# THERMO 2

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Mech Family
Notebooks

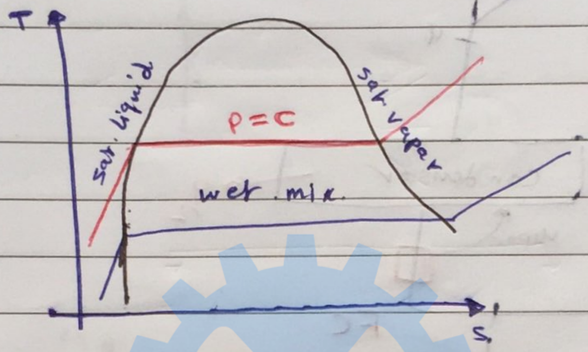
## ** CH 10 : Vapor power cycles :-

$$\boxed{v_f \leq v < v_g}$$ wet mix.

$T > T_{sat}$
$p < P_{sat}$
$u \geq u_g$
$h \geq h_g$
} superheated vapor

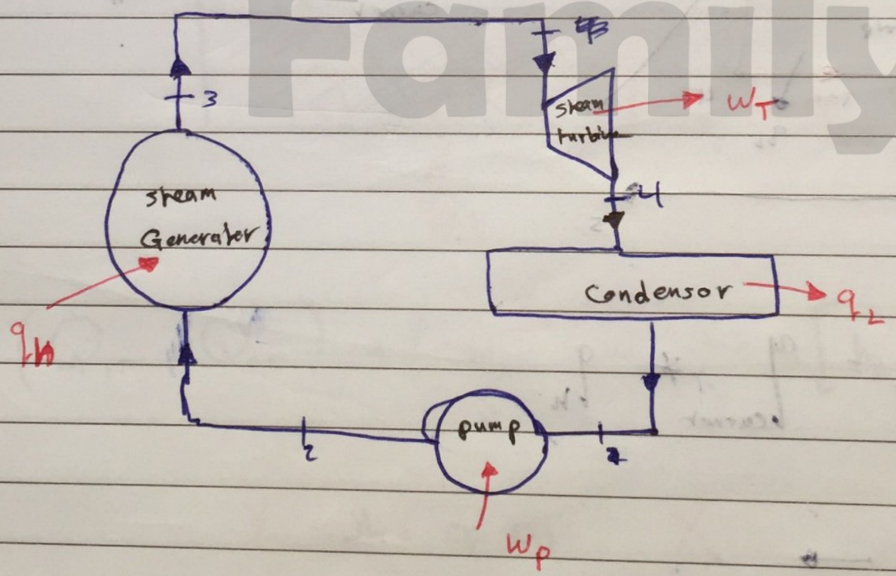
$p > P_{sat}$
$T < T_{sat}$
$u \leq u_f$
$h \leq h_f$
} comp. Liquid

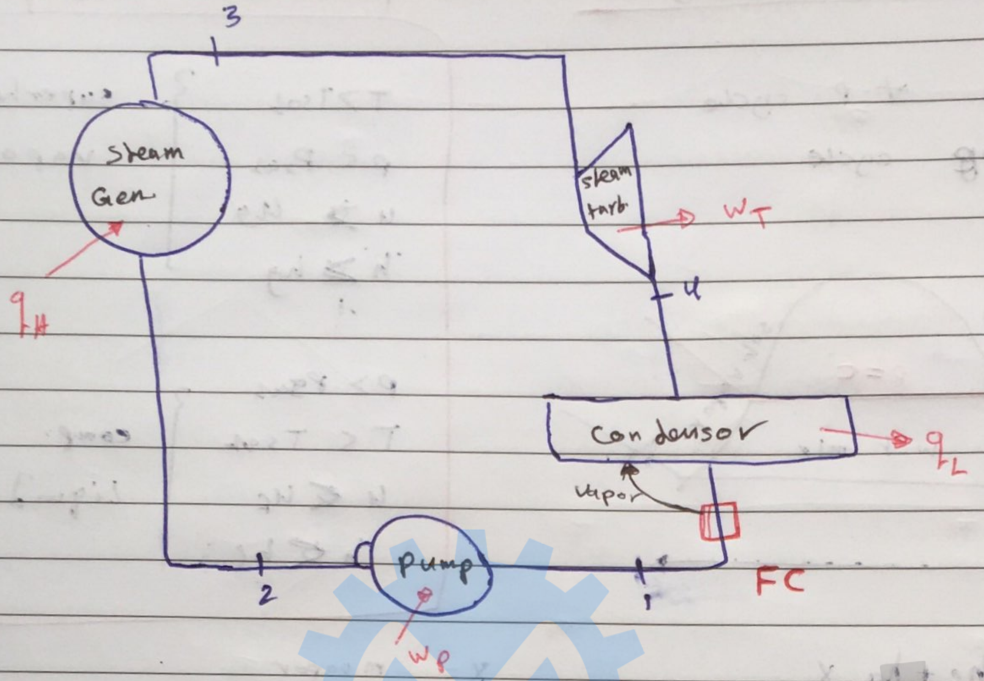
1. Carnot V.P. cycle.
2. RanKing cycle.

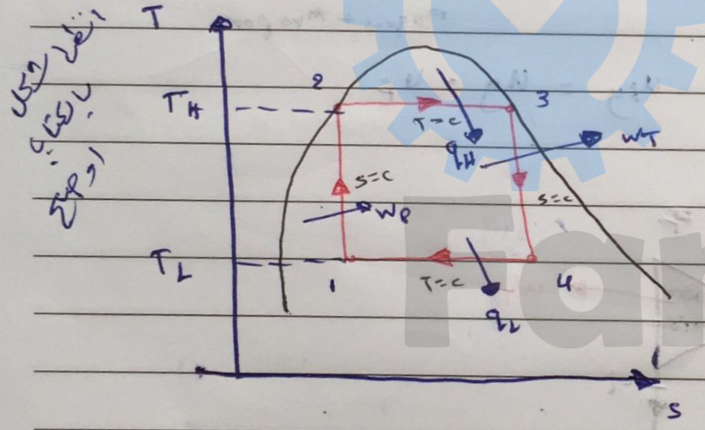


$$h = h_f + h_{fg}\,x \qquad x = \frac{m\,vapor}{m_{liquid} + m_{vapor}}$$

$$u = u_f + x\,u_{fg} \qquad u_{fg} = u_g - u_f$$



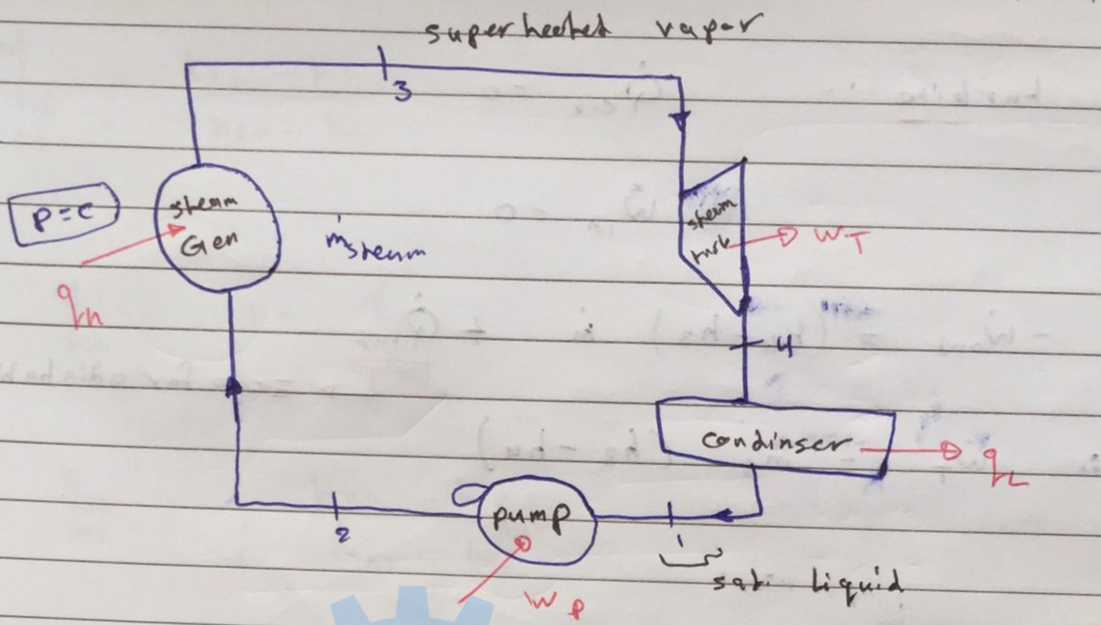


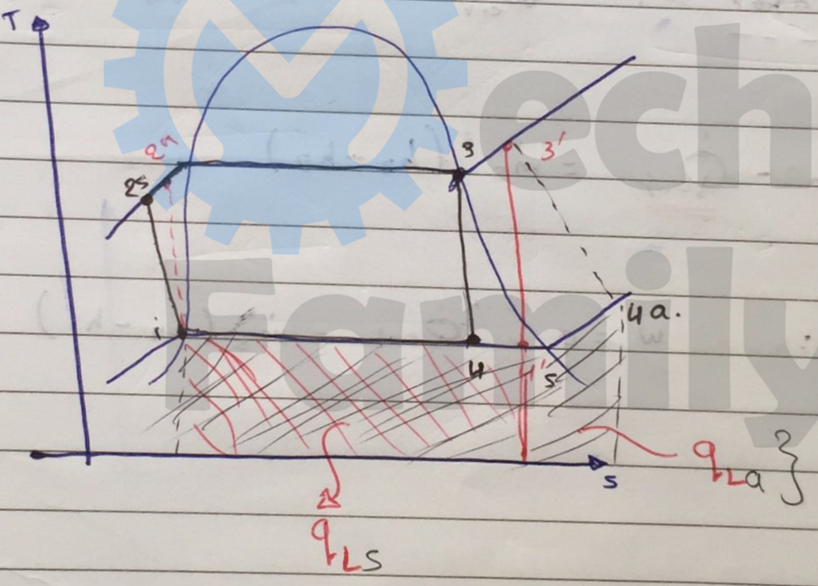


$$\eta_{H_{carnot}} = 1 - \frac{T_L}{T_H}$$

$$W_{max} = W_{reversible} = \eta_{carnot} * q_h$$

Flash champer →





هنه اكبر
لأنه بتعامل مع
حرارة أكبر

$$\left(\dot{Q}_{in} - \dot{Q}_{out}\right) + \left(\dot{W}_{in} - \dot{W}_{out}\right) = \dot{m}\left[h_f - h_i + \Delta KE + \Delta PE\right]$$

$$X \quad \underbrace{dh = c_p\, \Delta T}_{} \quad X$$

لأنه هاي المعادله للهواء وهون بهاي
ال cycle اشي ثاني water

**steam turbine :-** $\dot{Q}_{c.v} = 0$

$\dot{W}_{in} = 0$

$-\dot{W}_{out} = (h_4 - h_3)\,\dot{m} + \underbrace{\dot{Q}_{out}}_{\text{zero for adiabatic.}}$

$\therefore \quad \dot{W}_T = \dot{m}_s\,(h_3 - h_4)$

**steam generator :-** $\dot{W}_{c.v} = 0$ , $\dot{Q}_{out} = 0$

$\therefore \quad \dot{Q}_{in} - \dot{Q}_{out} = \dot{m}_s\,(h_3 - h_2)$

**condenser :-** $\dot{W} = 0$ , $\dot{Q}_{out} = \dot{m}_s\,(h_4 - h_1)$

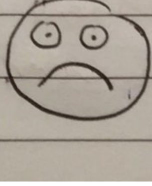
**pump :-**

$$\dot{W}_P = \cancel{\dot{m}_s}\,(h_2 - h_1)$$
$$= \cancel{\dot{m}_s}\,(V_{f_1})\,\underbrace{(P_2 - P_1)}_{\text{in Kpa}}$$

$$\boxed{h_2 - h_1 = v_{f_1}\,(P_2 - P_1)} \rightarrow$$ مفتاح حل
المسئلة

for $\boxed{s = c}$

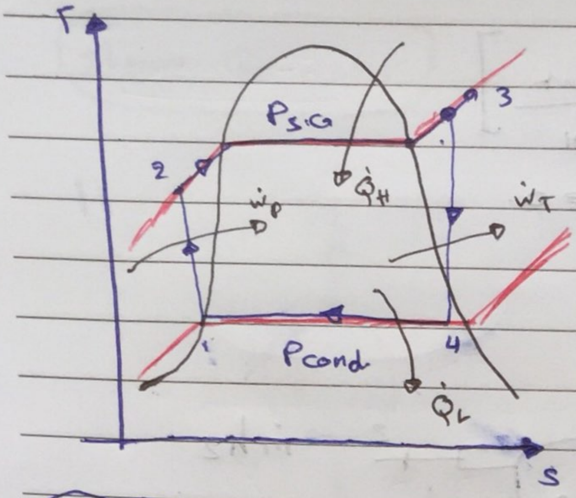
✗ $h_{2a} - h_1 = v_{f_1}\,(P_2 - P_1)$

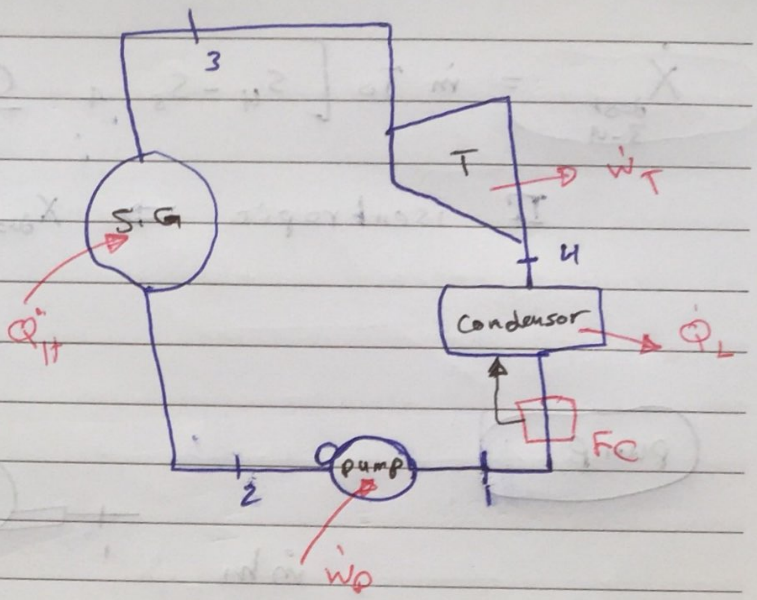


$$\eta_{th_{BS}} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

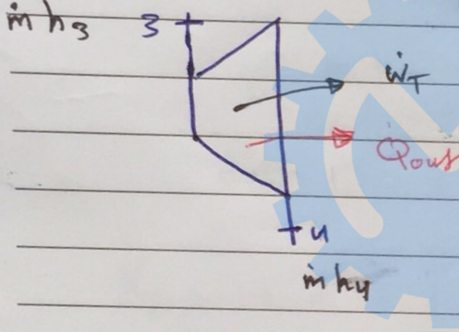
$$\eta_{th} = 1 - \frac{q_L}{q_H}$$

$$\eta_{th_{TS}} = \frac{h_{4a} - h_3}{h_{4s} - h_3}$$





Turbine



$$\dot m h_3 = \dot W_T + \dot m h_4 + \dot Q_{out}$$

$$\dot W_T = \dot m (h_3 - h_4) - \dot Q_{out}$$

$$\dot\Psi_{3\,max} = \left[h_3 - h_0 - T_0 (s_3 - s_0)\right] \dot m$$

$$\dot\Psi_{4\,min} = \dot m \left[h_4 - h_0 - T_0 (s_4 - s_0)\right]$$

$$\dot W_{T rev} = \dot\Psi_3 - \dot\Psi_4$$

zero for adiabatic

$$= \dot m \left[h_3 - h_4 - \cancel{T_0 (s_3 - s_4)}\right]$$

$h_0 = h_f$ @ $P_0, T_0$

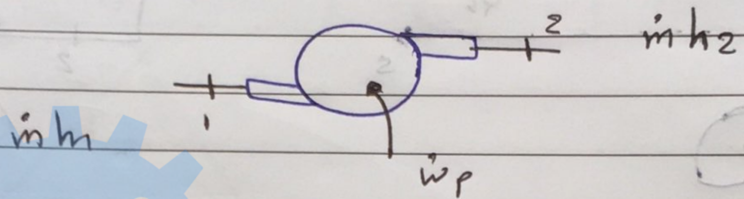
$s_0 = s_f$ @ $P_0, T_0$

$$\boxed{I_{rev} = \dot W_{rev} - \dot W_{actual}}$$

$$\dot{X}_{\substack{dest\\3-4}} = \dot{m}\, T_0 \left[ s_4 - s_3 + \frac{\dot{Q}_{out}}{T_H} \right]$$

If isentropic $\Rightarrow X_{dest} = 0.$

**pump**



$$\dot{m}\, h_2 = \dot{m}\, h_1 + \dot{w}_p$$

$$\therefore\ \dot{w}_p = \dot{m}\,(h_2 - h_1)$$

$$= \dot{m}\, v_{f_1}\, (P_2 - P_1)_{s=c}$$

$$\dot{W}_{\substack{rev\\in}} = \dot{\Psi}_2 - \dot{\Psi}_1$$

$$= \dot{m}\left[ (h_2 - h_1) - T_0\, (s_2 - s_1) \right]$$

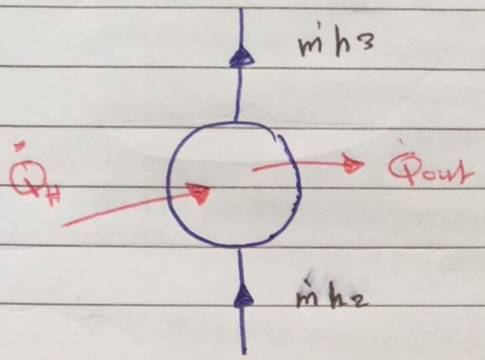
→ $I_{rev} = \dot{W}_p - \dot{W}_{\substack{rev\\in}}$

$$\dot{X}_{\substack{dest\\1-2}} = \dot{m}\, T_0 \left[ s_2 - s_1 \right]$$

If Isentropic $\rightarrow \dot{X}_{dest} = 0$

## Steam Generator

$\dot{w} = 0$



$$\dot m h_2 + \dot Q_H = \dot m h_3 + \dot Q_{out}$$

$$\Longrightarrow \dot Q_H = \dot m ( h_3 - h_2 ) + \dot Q_{out}$$

$$\dot X_{dest\,2-3} = \dot m T_0 \left[ s_3 - s_2 - \frac{q_H}{T_H} \right]$$

$$+ \frac{q_{out}}{T_H}$$

وإذا كان عندي اصلاً $q_{out}$

$$\left. \begin{aligned} \dot X_{heat\,in} &= \left( 1 - \frac{T_0}{T_H} \right) \dot Q_H \\ \dot X_{heat\,min} &= \dot \Psi_3 - \dot \Psi_2 \end{aligned} \right\}$$

Condensor.

$$\dot{Q}_L = \dot{m}\,(h_4 - h_1)$$

$$\dot{X}_{\substack{heat\\out}} = \left(1 - \frac{T_o}{T_L}\right)\dot{Q}_H$$

$$\dot{X}_{\substack{heat\\out}} = \dot{\psi}_4 - \dot{\psi}_1$$

## Comparison between different methods to improve cycle efficiency

A steam power plant operates on a simple ideal Rankine cycle. The steam enters the turbine at 3 MPa and 350 °C. It is then condensed in the condenser at 10 kPa. Calculate:

1) The engine performance parameters for the above power plant.
2) The performance parameters if the steam is superheated to 600 °C instead of 350 °C keeping rest of conditions the same.
3) The performance parameters if the boiler pressure is raised to 15 MPa keeping turbine inlet at 350 °C.
4) The performance parameters if the boiler pressure is raised to 15 MPa keeping turbine inlet at 600 °C.
5) The performance parameters if for case No. (1) the condenser pressure is lowered to 7.5 kPa.

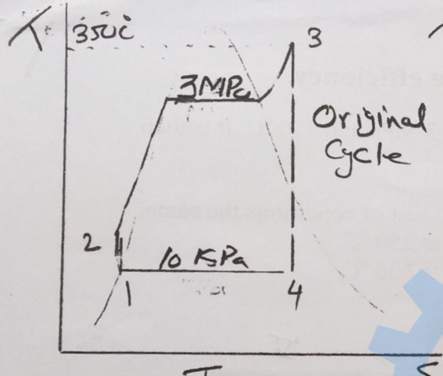
❖ **Results comparison for the above cases.**

| | I | II | III | IV | V |
|---|---|---|---|---|---|
| | **Ideal** | **Increase $T_{max}$** | **Increase $P_{boiler}$** | **Increase $P_{boiler}$ & $T_{max}$** | **Decrease $P_{condenser}$** |
| **Pump Work (kJ/Kg)** | 3.0199 | 3.0199 | 15.14 | 15.1399 | 3.016 |
| **Heat Input (kJ/Kg)** | 2920.48 | 3487.48 | 2485.47 | 3375.36 | 2943.51 |
| **Steam Quality X4** | 0.8123 | 0.9144 | 0.6388 | 0.803 | 0.8035 |
| **Turbine Work (kJ/Kg)** | 979.6 | 1302.375 | 971.87 | 1467.4 | 1013.18 |
| **Heat Output (kJ/Kg)** | 1943.89 | 2188.12 | 1528.74 | 1923.1 | 1933.349 |
| **Net Work out (kJ/Kg)** | 976.58 | 1299.355 | 956.73 | 1452.26 | 1010.164 |
| **Thermal Efficiency (%)** | 33.4 | 37.25 | 38.49 | 43.025 | 34.31 |
| **Carnot Efficiency (%)** | 48.82 | 63.48 | 48.82 | 63.48 | 49.71 |
| **Relative Efficiency (%)** | 68.41 | 58.67 | 78.84 | 67.77 | 69.02 |

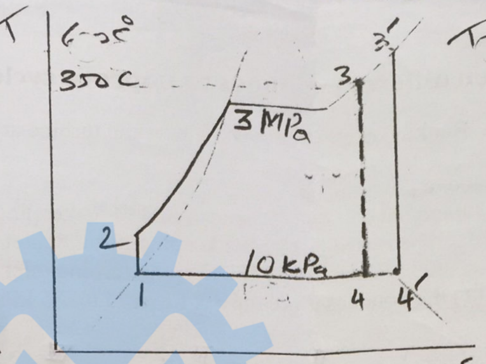
← مشكلة Thermal stress على ريشه ال Turbine

← مشكلة بدنا كمية Fuel كتير

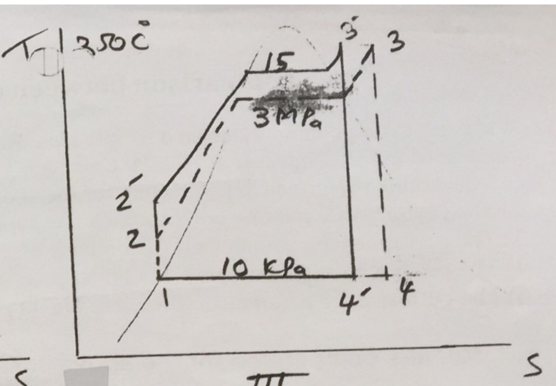
كمان $q_L$ بتروح عالبحر وإذا ارتفعت حرارة المي بيموت السمك



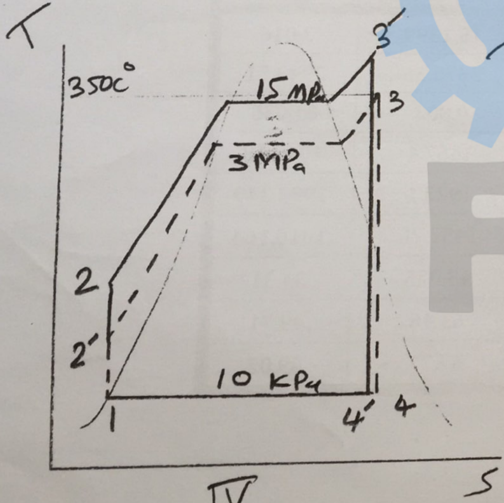
I



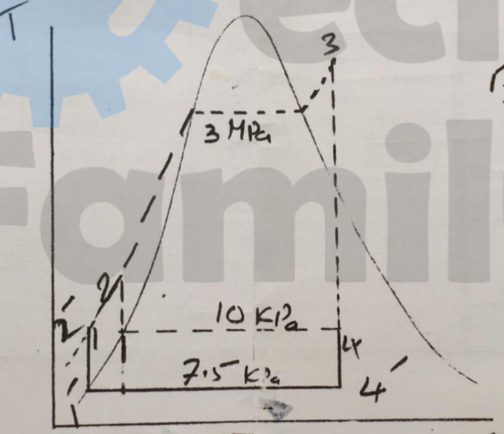
II



III



IV



V

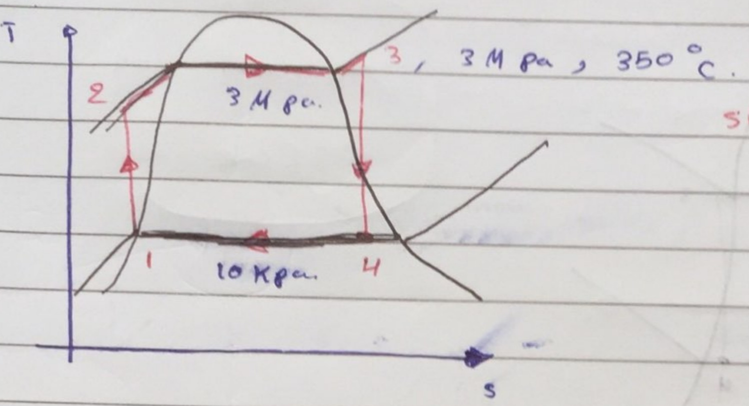
1-2-3-4 Original Cycle

1'-2'-3'-4' Modified Cycle

كل ما إتجهنا بال T S diag. لليسار بتقل الإنثالبي

(lec) 22

How to improve $\eta_{th}$ :-



since $T_3 > T_{sat}$ @ 3 M pa

$\Downarrow$

S.H

$h_3 = 3116.1$

$s_3 = 6.745$.

$q_h = 2920.48 \frac{KJ}{Kg}$

(1) sat. liquid, 10 Kpa

$h_f = 191.81$

$h_{fg} = 2392.1$

$s_f = 0.6492$

$s_{fg} = 7.4996$

$v_f = 0.00101$

$s_g = 8.1488$

(2) comp. liquid, 3 M pa

$P_2 = 3000$ Kpa.

$s_2 = s_1$

$$W_{p_{rev}} = v_{f_1} (P_2 - P_1)$$

$$= h_2 - h_1$$

$$= (0.00101)(3000 - 10)$$

$$= 3.0199 \text{ KJ/Kg}$$

$$= \underline{\underline{h_2}} - h_1 \Longrightarrow h_2 = 194.83 \text{ KJ/Kg}.$$

??.

(4) $s_4 = s_3$, $P = 10$ Kpa.

since $s_4 < s_g |_{10 Kpa}$.

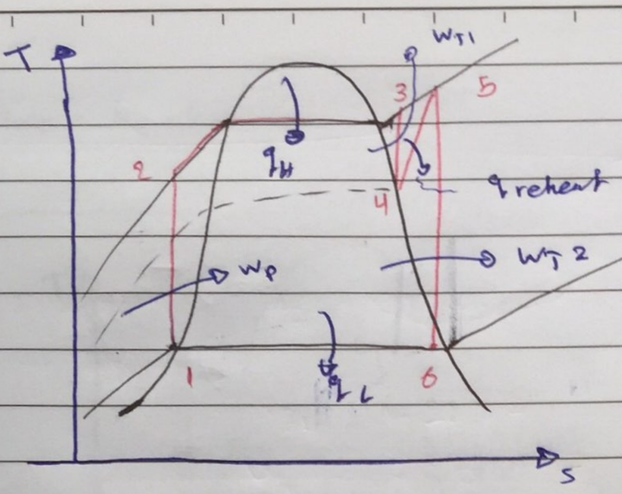
$\therefore$ wet mix.

$$s_4 = s_{f_1} + X_4 s_{fg_1}$$

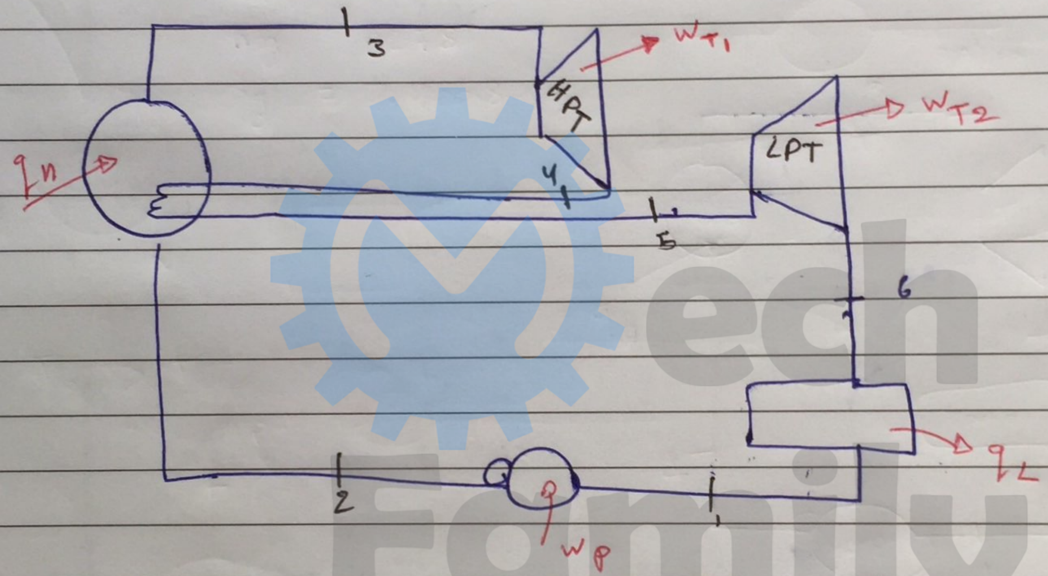
$$\therefore X_4 = \frac{s_4 - s_{f_1}}{s_{fg_1}} = 0.8128.$$

$$h_4 = h_{f_1} + X_4 h_{fg}$$

$$= 2136.148 \frac{KJ}{Kg}$$



Reheat cycle.



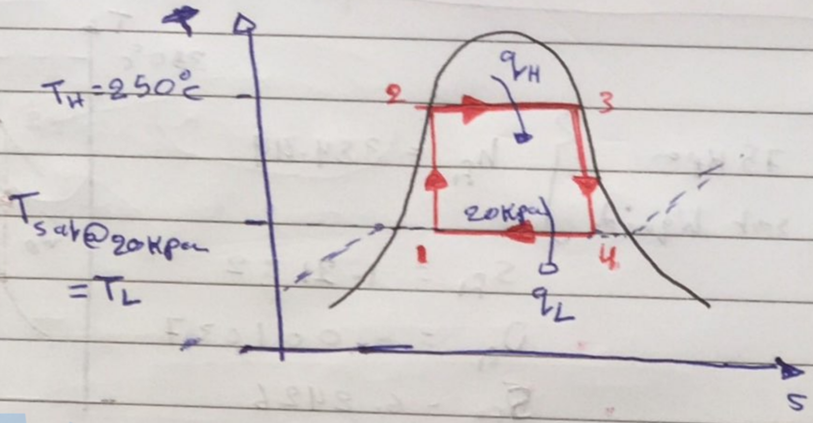
$w_T = w_{T_1} + w_{T_2} = (h_3 - h_4) + (h_5 - h_6)$

$q_h = (h_3 - h_2) + (h_5 - h_4)$

$q_L = h_6 - h_1$

$w_p = h_2 - h_1$

**Q 10.2** Carnot , $H_2O$.



$T_L = T_{sat\ @\ 20kPa} = 60.06°c$

$\eta_{carnot} = 1 - \frac{60.06}{250}$ X انتبه للتحويل

$\eta_{carnot} = 1 - \frac{60.06 + 273}{250 + 273} = 0.363$

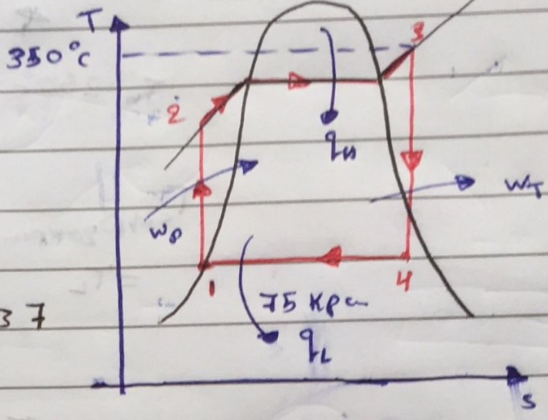
$q_{in\ 2-3} = h_3 - h_2 = h_{fg\ @\ 250°c} = 1715.3\ KJ/Kg = T_H\ S_{fg}$
$= T_H\ (S_3 - S_2)$

$W_{net} = \eta_{carnot} * q_H = 623\ KJ/Kg$

$W_{net} = q_H - q_L \Longrightarrow \therefore q_L = 1092.3\ KJ/Kg$

$q_L = T_L\ (S_4 - S_1)$
$= T_L\ (S_3 - S_2)$

## Ex : 10.1 & Ex : 10.7



① 75 Kpa sat liquid } $h_{f_1} = 384.44$

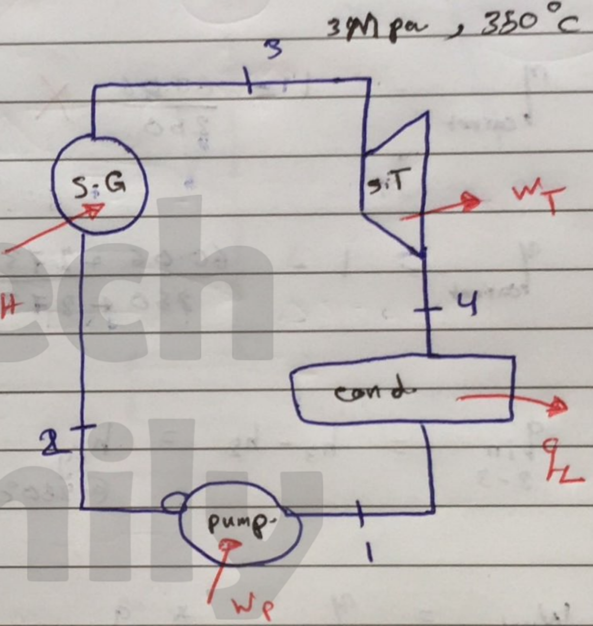
$S_{f_1} = 1.2132$

$\vartheta_{f_1} = 0.001037$

$S_{fg} = 6.2426$

$h_{fg} = 2278$

$S_g = 7.4558$



③ 3 Mpa

350°K

$T_3 > T_{sat} @ 3Mpa$

∴ SH

$h_3 = 3116.1$

$S_3 = 6.743$

② $W_P = h_2 - h_1$

$= \vartheta_{f_1} (P_2 - P_1)$

$= 0.001037 \ (3000 - 75)$

$= 3.033$ KJ / Kg

$h_2 = 387.473$ KJ / Kg

$S_2 = S_1$

$\boxed{4}$ 75 Kpa. $s_3 = s_4 = 6.745 \frac{KJ}{Kg}$

Since $s_4 < s_{g}$ 75 Kpa.

$\therefore$ wet mix.

$s_4 = s_{f_1} + x_4 \, s_{fg}$

$\therefore x_4 = 0.8861$

$\therefore h_4 = h_{f_1} + x_4 \, h_{fg} = 2403.06$ KJ/Kg

$q_h = h_3 - h_2 = 2728.63$

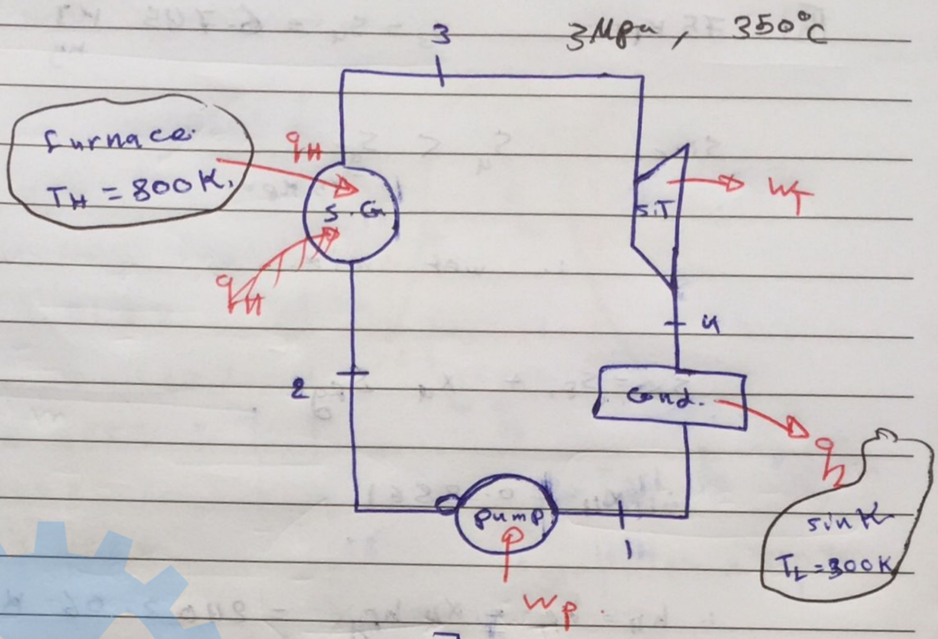
$q_L = h_4 - h_1 = 2018.6$

$W_{net} = 710$ KJ/Kg

$\eta_{th} = 0.2602$

$W_{Turbine} = h_3 - h_4 = 713.04$ KJ/Kg

Ex 10-7



$$X_{dest} = T_0\left[s_f - s_i - \frac{q_{in}}{T_H} + \frac{q_{out}}{T_L}\right]$$

process (1-2) pump , 3-4 (Turbine) , $\Delta S = 0$.

$\therefore X_{dest} = 0$

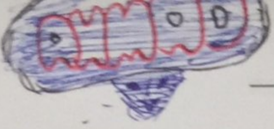
process (2-3) , (P = c) , $q_{in}$

$$X_{dest} = 300\left[6.745 - 1.2132 - \frac{2728.63}{800}\right]$$

$$= 636.305 \text{ KJ/kg}$$

process (4-1) , P = c , $q_{out}$

$$X_{dest} = 300\left[1.2132 - 6.745 + \frac{2018.6}{300}\right] = 359.06 \frac{KJ}{kg}$$



$$X_{\substack{dest\\cycle}} = 0 + 636.305 + 0 + 359.06$$

$$= 995.365 \text{ KJ/Kg}$$

$$\eta_{carnot} = 1 - \frac{T_L \overset{300\,K}{}}{T_H \underset{800K}{}} = 0.625.$$

$$\eta_{II} = \frac{\eta_{th}}{\eta_{carnot}} = \frac{0.2602}{0.625} = 41.73 \%$$

$$X_{expended} = X_{\substack{heat\\in}} + w_p$$

$$= \left(1 - \frac{T_0}{T_L}\right) q_H + w_p$$

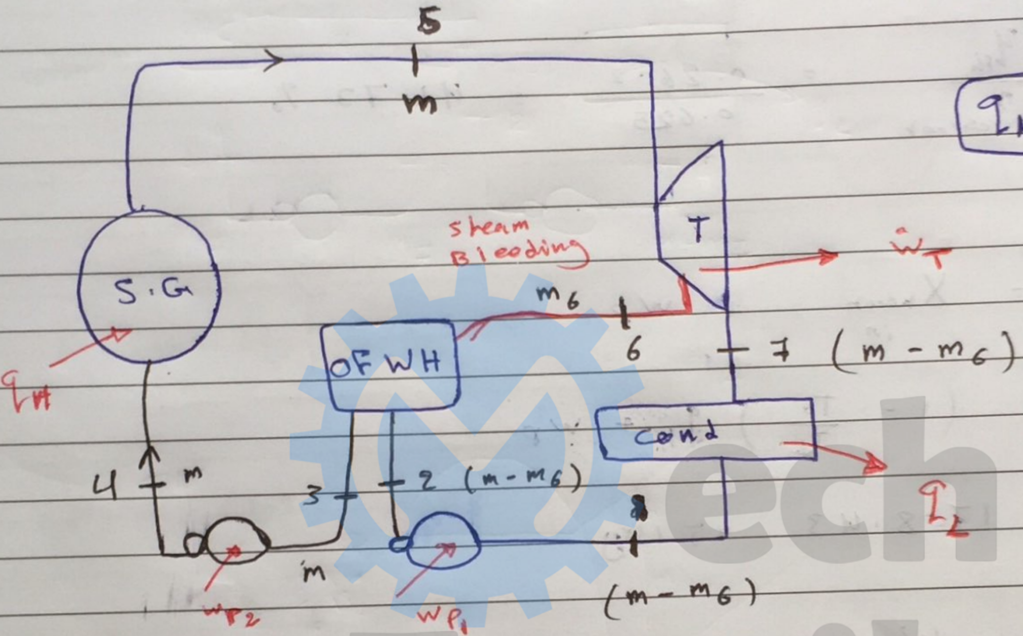
$$= 1708.43 \text{ KJ/Kg}$$

$$X_{recovered} = W_{Turbine}$$

→ Rankine cycle with regeneration

1 open Feed water heater

2 closed Feed water heater



$$\boxed{q_h = h_5 - h_4}$$

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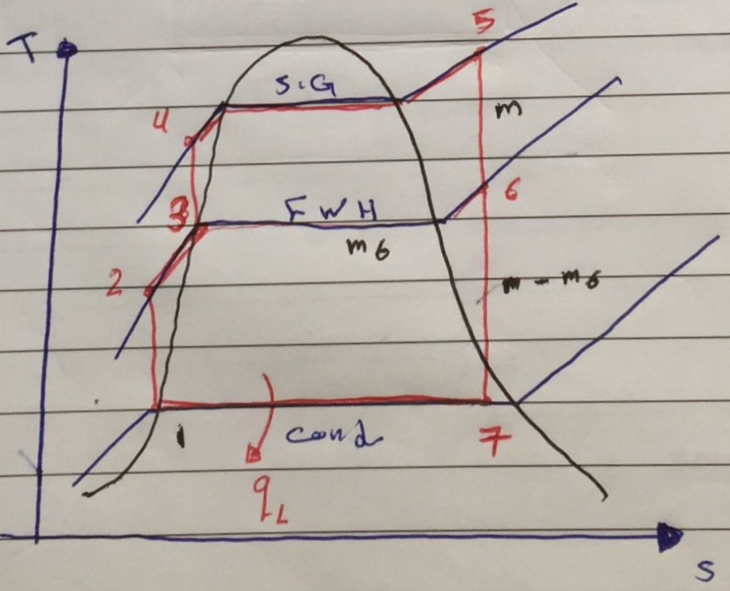
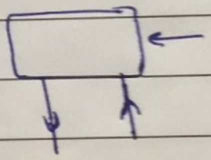
$$\eta_{th} = \frac{W_{net}}{q_h}$$

$P_6 = P_2 = P_3$

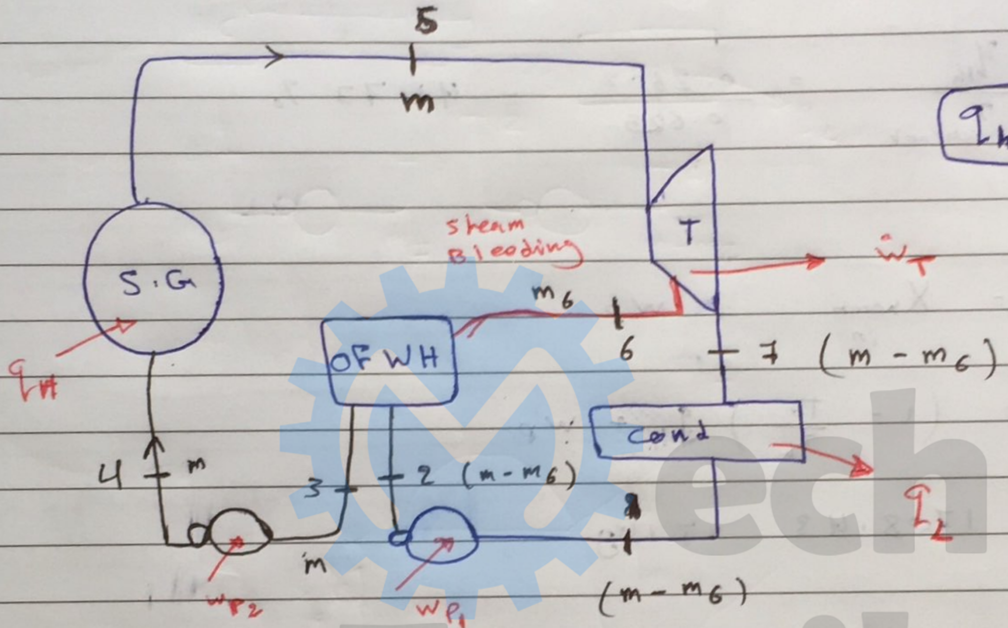




## → Rankine cycle with regeneration

$\boxed{1}$ open Feed water heater

$\boxed{2}$ closed Feed water heater

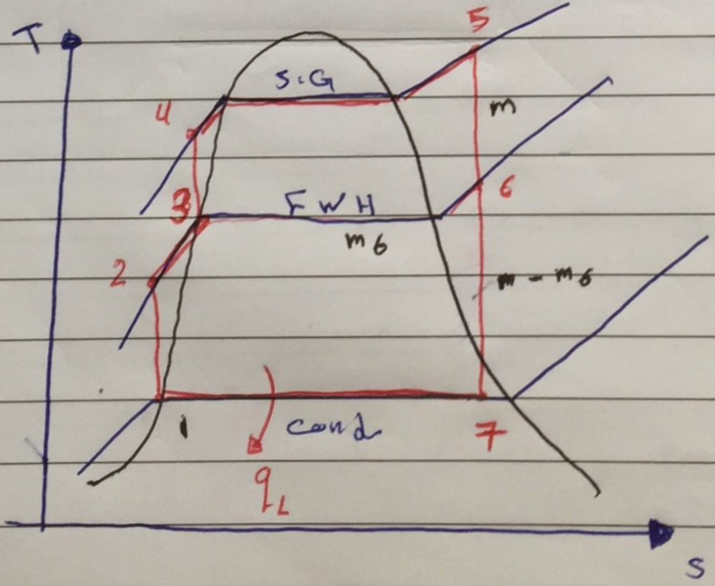


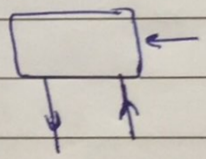
$$\boxed{q_h = h_5 - h_4}$$

فقط لها

$$\eta_{th} = \frac{W_{net}}{q_{in}}$$

$P_6 = P_2 = P_3$





$$\dot W_T = \dot m (h_5 - h_6) + (\dot m - \dot m_6)(h_6 - h_7)$$

$$\dot W_P = (\dot m - \dot m_6)(h_2 - h_1) + \dot m (h_4 - h_6)$$

$$\dot Q_H = \dot m (h_5 - h_4)$$

$$\dot Q_L = (\dot m - \dot m_6)(h_7 - h_1)$$

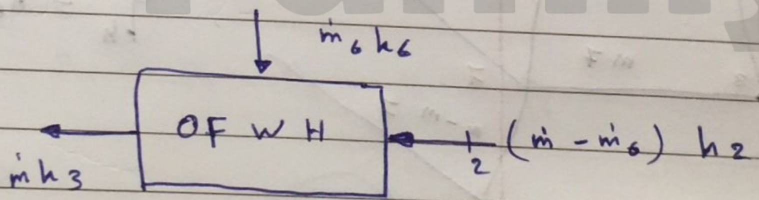
$$W_T = (h_5 - h_6) + (1 - Y)(h_6 - h_7)$$

$$W_P = (1 - Y)(h_2 - h_1) + (h_4 - h_3)$$

$$q_H = (h_5 - h_4)$$ [redacted]

$$q_L = (1 - Y)(h_7 - h_1)$$

$$Y = \frac{\dot m_6}{\dot m}$$



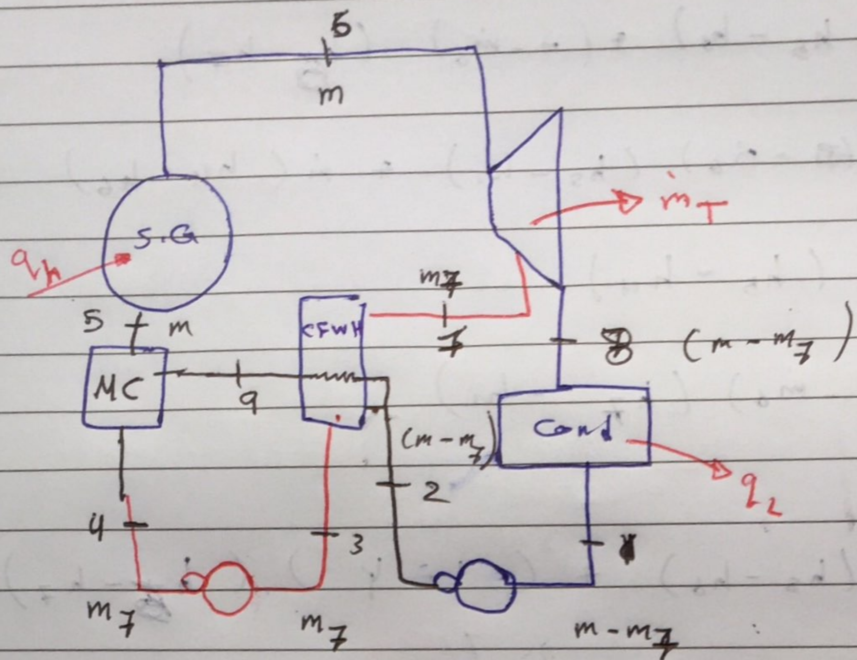
$$\left( (\dot m - \dot m_6) h_2 + \dot m_6 h_6 = \dot m h_3 \right) / \dot m$$

$$(1 - Y) h_2 + Y h_6 = h_3$$

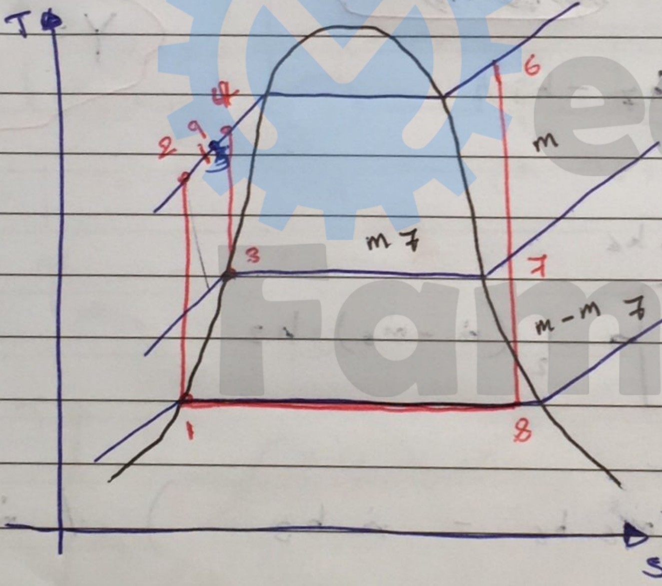
$$Y = \frac{h_3 - h_2}{h_6 - h_2} * 100 \%$$

بتعطيني نسبة ال steam
اللي اخذناه من
turbine

$$= \ldots \%$$



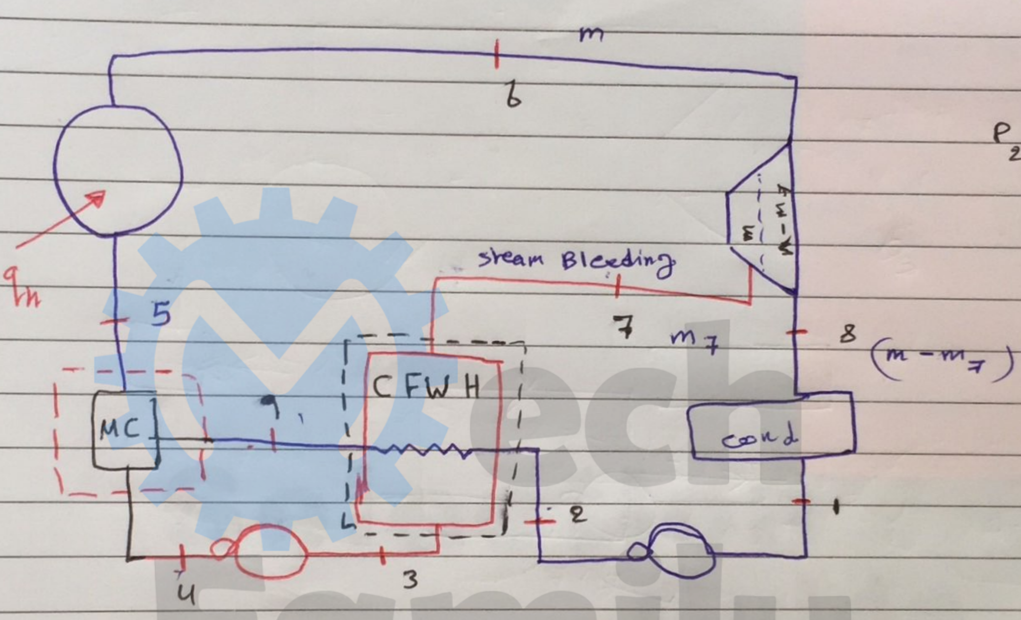
$P_6 = P_5 = P_9 = P_4 = P_2$



$q_h = h_6 - h_5$

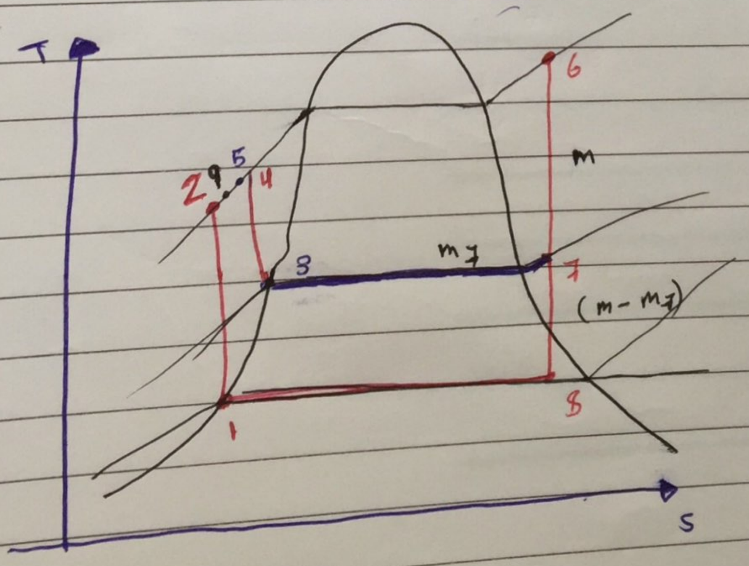
EES ≡ Engineering Equation solve. (F-Chart)

- Rankine cycle with Regeneration.
  - OFWH
  - CFWH
- cogeneration cycle.



$P_2 = P_3 = P_6$

$P_2 = P_9 = P_4 = P_5 = P_6$



$q_h = h_6 - h_5$

No.

**Turbine** $\dot{W}_T = \dot{m}(h_6 - h_7) + (\dot{m} - \dot{m}_7)(h_7 - h_8)$

**pump** $\dot{W}_P = (\dot{m} - \dot{m}_7)(h_2 - h_1) + \dot{m}_7 (h_4 - h_3)$

**S.G** $\dot{Q}_H = \dot{m}(h_6 - h_5)$

**cond.** $\dot{Q}_L = (\dot{m} - \dot{m}_7)(h_8 - h_1)$

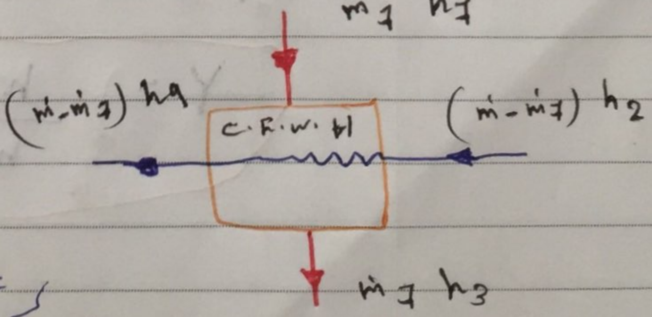
$$\downarrow \quad (/\dot{m})$$

$$\dot{w}_T = (h_6 - h_7) + (1 - Y)(h_7 - h_8)$$

$$\dot{w}_P = (1 - Y)(h_2 - h_1) + Y(h_4 - h_3)$$

$$\dot{q}_H = (h_6 - h_5)$$

$$\dot{q}_L = (1 - Y)(h_8 - h_1)$$



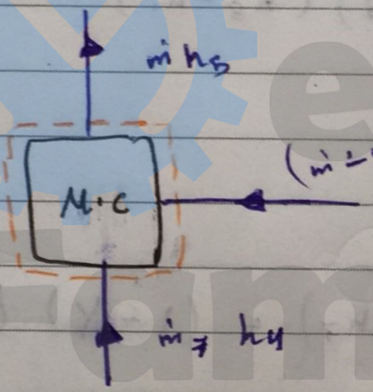
$$\dot{m}_7 h_7 + (\dot{m} - \dot{m}_7) h_2 = (\dot{m} - \dot{m}_7) h_9 + \dot{m}_7 h_3$$

$$(/\dot{m}) \quad \Rightarrow$$

No.

$$\gamma h_7 + (1-\gamma) h_2 = (1-\gamma) h_9 + \gamma h_3$$

$$\gamma = \frac{h_9 - h_2}{(h_7 - h_3) + (h_9 - h_2)}$$



$$\boxed{\begin{array}{c} T_3 = T_9 \\ h_3 = h_9 \end{array}}$$

$$\dot{m}_7 h_4 + (\dot{m} - \dot{m}_7) h_9 = \dot{m} h_5$$

$$\gamma (h_4) + (1-\gamma) h_9 = h_5$$

$$\gamma (h_4 - h_9) + h_9 = h_5$$

$$\boxed{\gamma = \frac{h_5 - h_9}{h_4 - h_9}}$$

No.

$$Y = \frac{h_9 - h_2}{(h_7 - h_3) + (h_9 - h_2)}$$

$$h_5 = (1 - Y)\, h_9 + Y\, h_4$$

$$\boxed{T_3 = T_9}$$
$$\boxed{h_9 = h_3}$$

$$\boxed{Y = \frac{h_3 - h_2}{h_7 - h_2}}$$

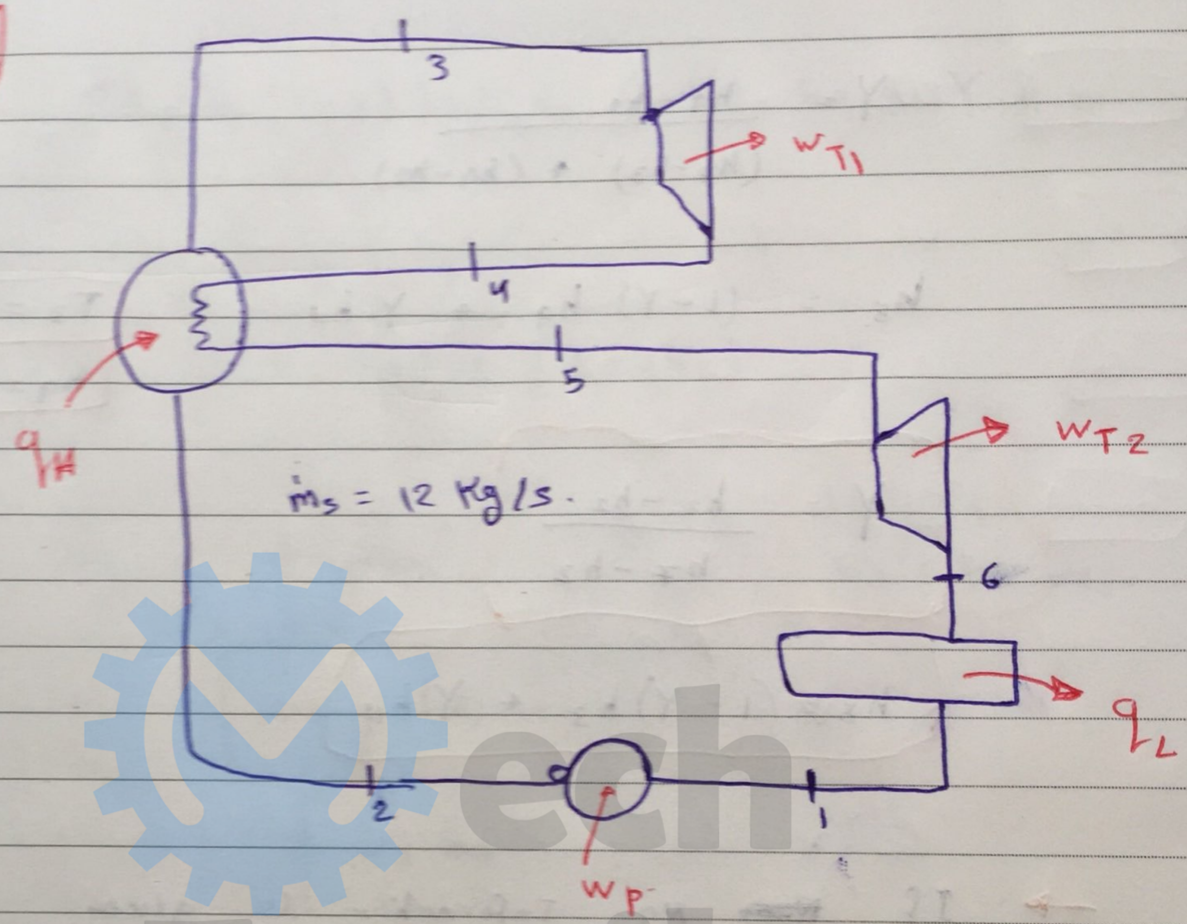
$$\boxed{h_5 = (1 - Y)\, h_3 + (Y)\, h_4}$$

→ If No Information is given about either $h_9$, $h_5$ or $Y$ Then assume $T_9 = T_3$ (Effectivness = $\epsilon$ = 100%) & hence. $h_9 = h_3$

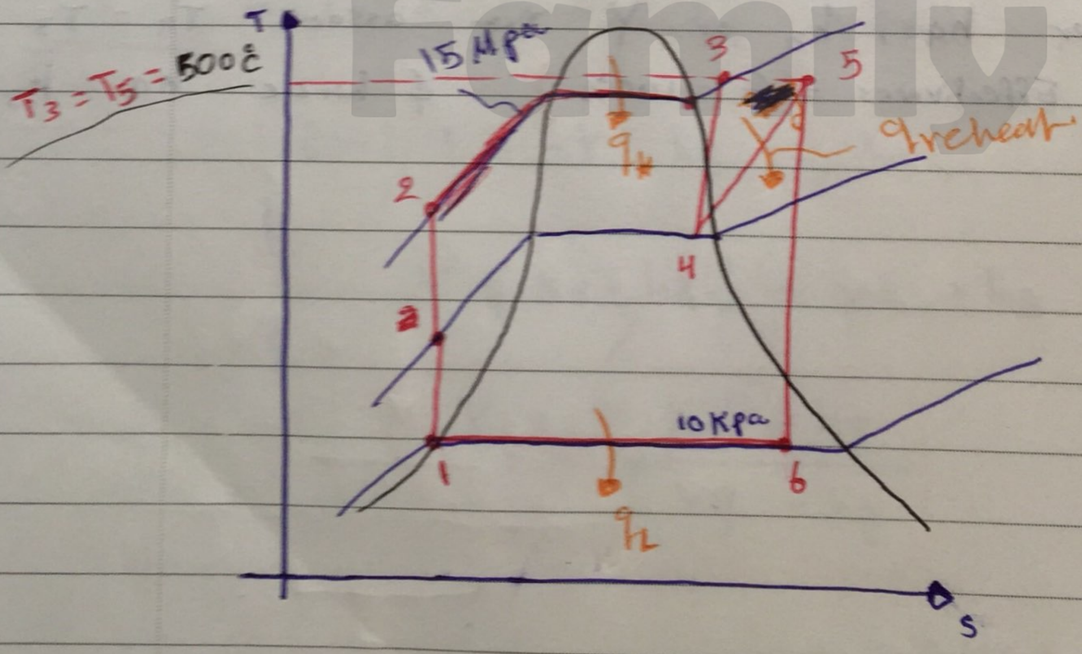
No.

Q. 10-37

7th Ed.



$\dot{m}_s = 12$ Kg/s.



$X_6 = 0.9$

$\boxed{1:20}$

No.

point $\boxed{1}$ sat. Liquid @ 10 Kpa

$h_f$ = 191.81

$h_{fg}$ =

$v_f$ = 0.00101

$s_f$ =

$s_{fg}$ =

$s_g$ =

point $\boxed{2}$ comp. Liquid

$$h_2 = h_1 + v_{f1}(P_2 - P_1)$$

$$= 191.81 + 0.00101 (15000 - 10)$$

$$= 206.95 \ \frac{KJ}{Kg}$$

point $\boxed{3}$ super heated vapor

$T_3 = 500°c$

$P_3 = 15$ Mpa

$h_3 = 3310.8$

$s_3 = 6.3480$

point $\boxed{6}$ 10 Kpa.

$X_6 = 0.9$

$$h_6 = h_{f1} + X_6 \ h_{fg}$$

$$= 2344.7 \ \frac{KJ}{Kg}$$

$$s_6 = s_f + X_6 \ s_{fg}$$

$$= 7.3988$$

~~$P_5 = ??$~~

| | 2 Mpa<br>$p = ??$ | $P_5 = ??$ | $P = 2.5$ Mpa |
|---|---|---|---|
| 500 | $s = 7.4337$ | $\boxed{7.3988}$ | $s = 7.3254.$ |
| | | $h_5 =$ | |

$P_5 = 2.1611$ Mpa

$\simeq 2.16$ Mpa

$h_5 = 3468.88$

$h_4 = 2817.6$

$\eta_{th} = 42.5\%$

$\dot{Q}_{in} = \dot{Q}_h + \dot{Q}_{reheat}$

$= \dot{Q}_{3-2} + \dot{Q}_{Reheat}.$

$= 45039$ KW

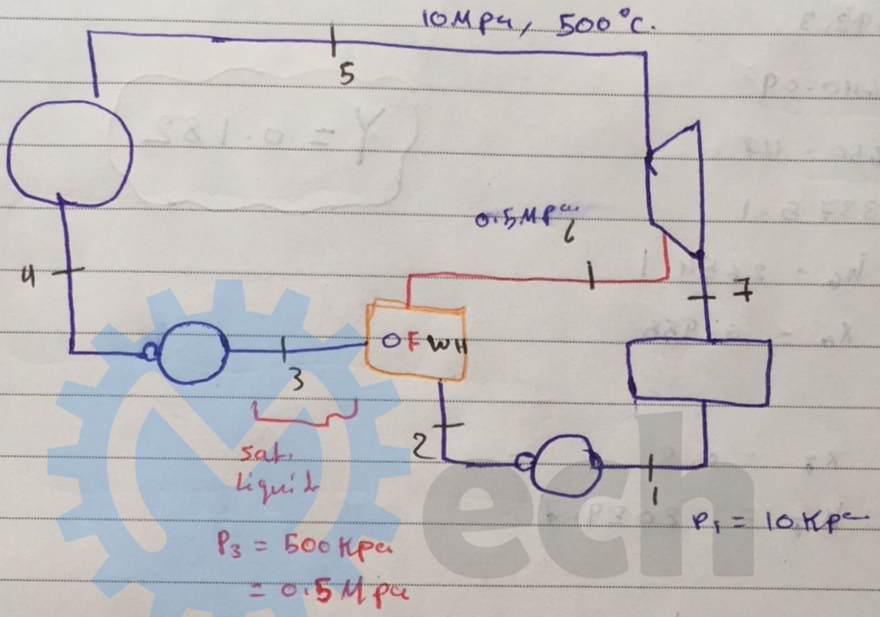
problem 10.38

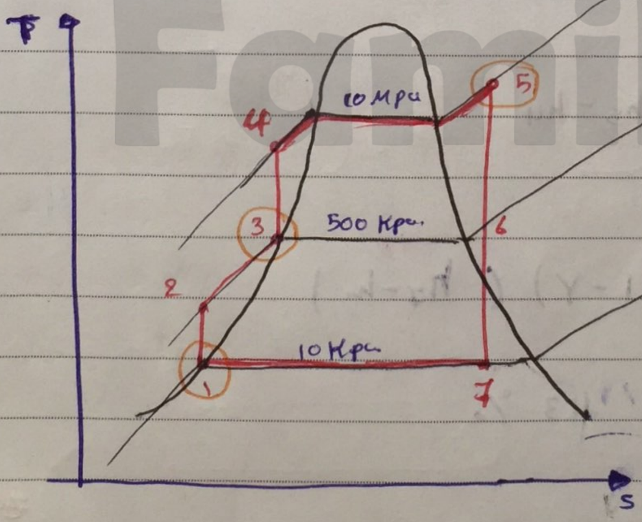
No.

Q.10-92

Vin.

$$\dot{W}_{net} = \dot{m}_s \left( w_T - w_P \right)$$
$$= 150 MW$$





$$h_2 = h_{f_1} + v_{f_1} \left( P_2 - P_1 \right) =$$

$$h_4 = h_{f_3} + v_{f_3} \left( P_4 - P_3 \right) =$$

No.

|  | h |
|---|---|
| 1 | 191.81 |
| 2 | 192.3 |
| 3 | 640.09 |
| 4 | 650.47 |
| 5 | 3375.1 |
| 6 | $h_6 = 2654.1$<br>$x_6 = 0.955$ |
| 7 | $x_7 = 0.8$<br>$h_7 = 2089.7$ |

$$\boxed{Y = 0.182}$$

$\dot m_s = 128$ kJ/s

$q_{in} = h_5 - h_4$

$=$

$q_{out} = (1 - Y)(h_7 - h_1)$

$\eta_{th} = 43\ \%$

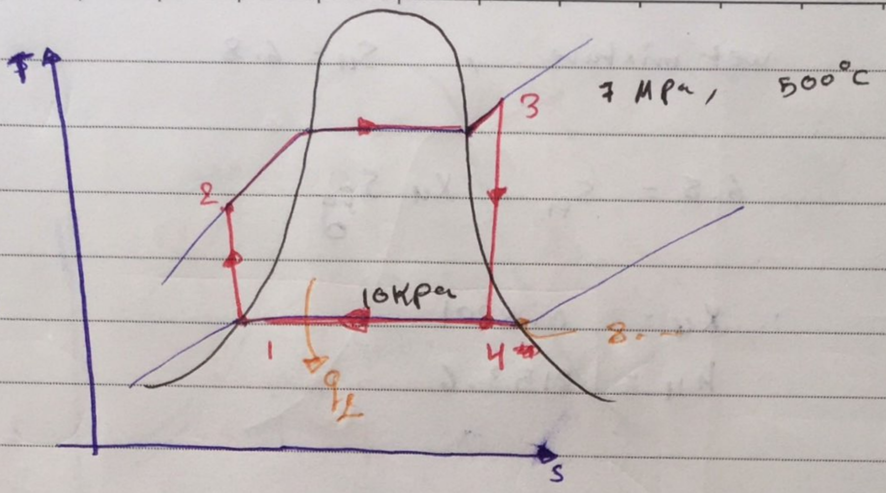
zero (surrounding)

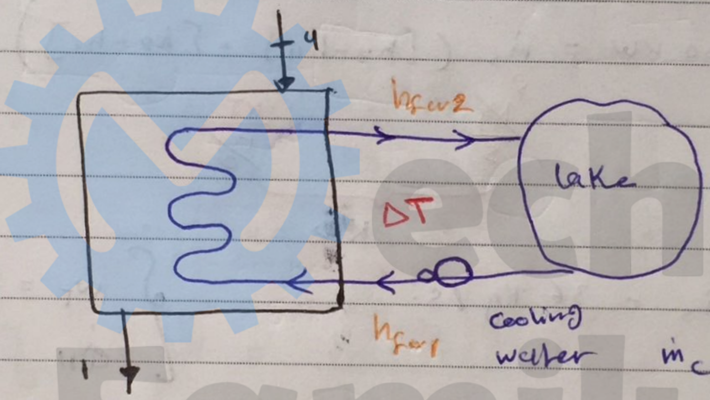
$$X_{dest} = T_0 \left( \sum_{out} \dot m s + \sum_{in} \dot m s + \cancel{\frac{q}{T}} \right)$$

10-18

$\dot{W}_{net} = 45\ MW$

$= \dot{m}_s (w_T - w_P)$





$\dot{m}_{cw} = 2000\ Kg/s$

③ 7 MPa , 500°C , S.H

$h_3 = 3411.4$

$s_3 = 6.8$

① 10 KPa , sat. Liquid

$h_1 = 191.81$

$v_f = 0.00101$

② $h_2 = h_1 + v_{f_1} (P_2 - P_1)$

$= 191.81 + 0.00101 ( 7000 - 10 )$

$= 198.87\ Kj/Kg$

$\boxed{4}$ wet mixture , $S_4 = 6.8$

$$6.8 = S_{f_1} + X_4 \, S_{fg}$$

$$\therefore X_4 = 0.8201$$

$$h_4 = 2153.6$$

$$45000 \text{ KW} = \underset{\frac{\cancel{Kg}}{s}}{\dot{m}_s} \left( \underbrace{[h_3 - h_4] - [h_2 - h_1]}_{\frac{KJ}{\cancel{Kg}}} \right)$$

Kw

$$\dot{m}_s = 36 \text{ Kg/s.}$$

$$\begin{cases} \dot{W}_T = 45.28 \text{ MW} \\ \dot{Q}_H = 115.6 \text{ Mw} \end{cases}$$

$$\eta_{th} = 39 \%$$

4.186

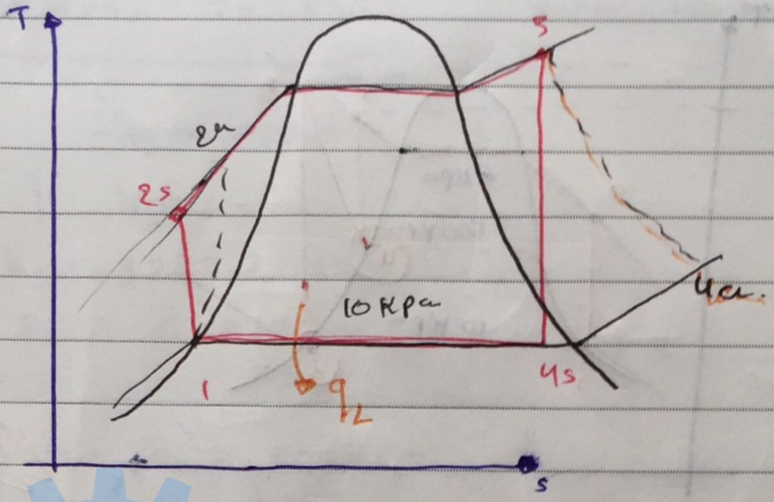
$$\underbrace{\dot{m}_s \, (h_4 - h_1)}_{\text{Heat Lossing Steam.}} = \dot{m}_w \, CP_w \, \Delta T_w$$

$$\boxed{\Delta T_w = 8.5 \, ^\circ C}$$

$\dot{m}_s \, \Delta h_{4-1} = \dot{m}_w \, (h_{f_{w_2}} - h_{f_{w_1}})$ لو فرضنا اعطانا درجة حرارة المي داخل ←

10-9

كل القيم
ب 10-8
تكون
isentropic



$$\eta_{TS} = 0.87 = \frac{h_3 - h_{4a}}{h_3 - h_{4s}}$$

$$\Rightarrow \boxed{h_{4a} = 199.92}$$

$$\eta_{PS} = 0.87 = \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

$$\Rightarrow \boxed{h_{2a} = 2317.1}$$

$$45000 \text{ KW} = \dot{m}_s \left( (h_3 - h_{4a}) - (h_{2a} - h_1) \right)$$

$$\underbrace{\dot{m}_s = 41.43 \ \frac{kg}{s}}$$

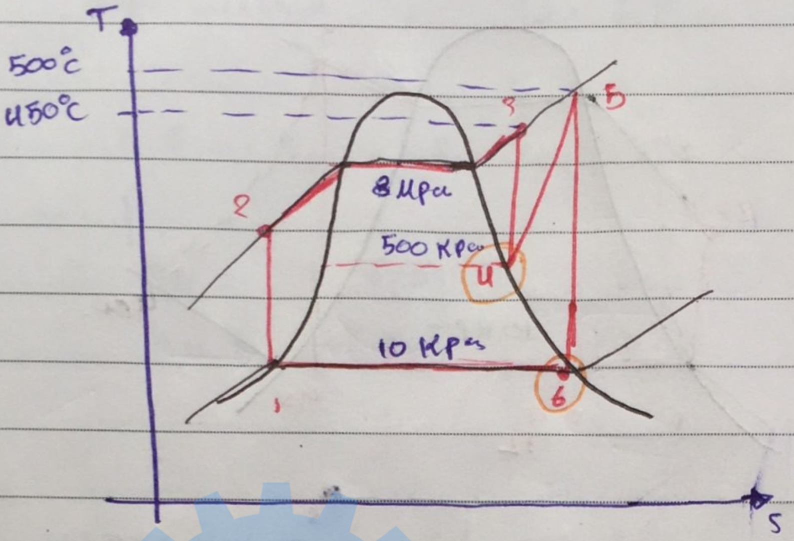
زادت حتى نعوض النقص في كفاءة ال turbine

$$\dot{m}_s \, (h_{4a} - h_1) = \dot{m}_w \, Cp_w \, \Delta T_w$$

$$\boxed{\Delta T_w = 10.5^\circ}$$

10.30

7th



4 & 6
بدهم تركيز

point 1 sat. liquid, 10 Kpa

$h_{f_1} = 191.81$

$v_{f_1} = 0.00101$

$S_{f_1} =$

$S_{fg} =$

$S_g =$

$h_{fg} =$

point 2 $w_p = h_2 - h_1 = v_{f_1} (P_2 - P_1)$ → only for isentropic

$h_2 = 191.81 + (0.00101)(8000 - 10)$

$$\boxed{h_2 = 199.88 \ KJ/Kg}$$

point $\boxed{3}$ $\underbrace{P_3 = 8 \text{ Mpa}, \quad T_3 = 450°c}$ super. heated

~~$h_3 = 3884$~~

~~$h_3$~~ =

$h_3 = 3273.3$

$s_3 = 6.5579$

$\boxed{\text{point } 5}$ $\left\{ \begin{array}{l} P_5 = P_4 = 500 \text{Kpa} \\ T_5 = 500°c. \end{array} \right.$

$h_5 = 3484.5$

$s_5 = 8.0893.$

point $\boxed{4}$ wet. mixture , $x_4 = 0.947$ , $h_4 = 2564.9$

$s_4 = s_3 = 6.5579.$

$P_4 = 500 \text{Kpa}$

$h^a$ = 2636.406

point $\boxed{6}$ $P_6 = 10 \text{ Kpa}$ , $s_6 = s_5 = 8.0893.$

wet mix.

$x_6 = 0.9924$

$h_6 = 2564.9.$

$\eta_{th} = 39.5 \%$

If $\dot{W}_{out} = 5000$ KW

$5000\ KW = \dot{m}_s ( W_T - W_P )$

$\rightarrow \dot{m}_s = 3.23 \frac{Kg}{s}$

If $T_H = 1000°c$ & $T_L = 20°c$
$= T_o$

$\eta_{II} =$

$\eta_{carnot} = 1 - \frac{T_L}{T_H} = 1 - \frac{(20 + 273)}{1000 + 273}$

$= 0.7698 = 76.98\ \%$

10-92

تم بالمحاضرة

حل

zero surroundings

$$X_{dest} = T_0 \left[ \sum \dot{m} s_{out} - \sum \dot{m} s_{in} + \cancel{\frac{Q}{T}} \right)$$

$$\dot{X}_{dest} = T_0 \left[ \dot{m} S_3 - \dot{m}_6 S_6 - (\dot{m} - \dot{m}_6) S_2 \right]$$

$$= \underbrace{T_0}_{303\,K} \left[ s_3 - y s_6 - (1-y) s_2 \right]$$

No.

**10.47** CFWH

Assume

$T_9 = T_3$

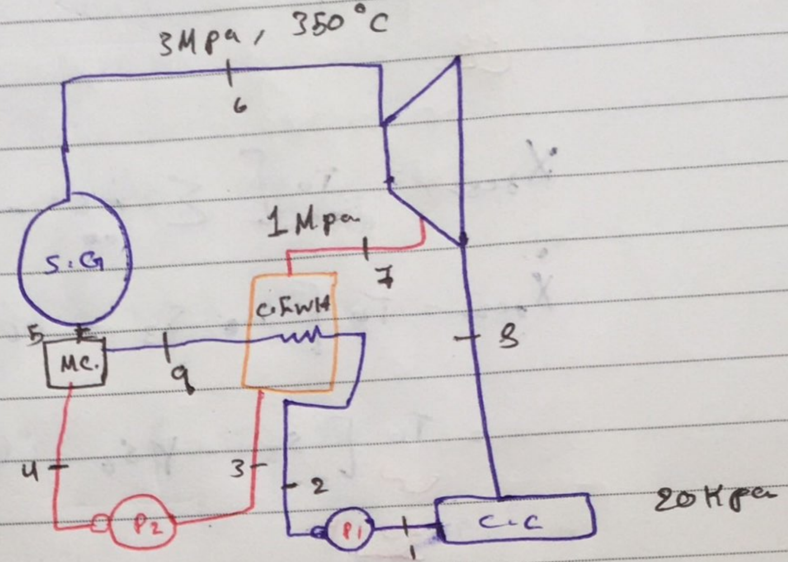
$h_9 = h_3$

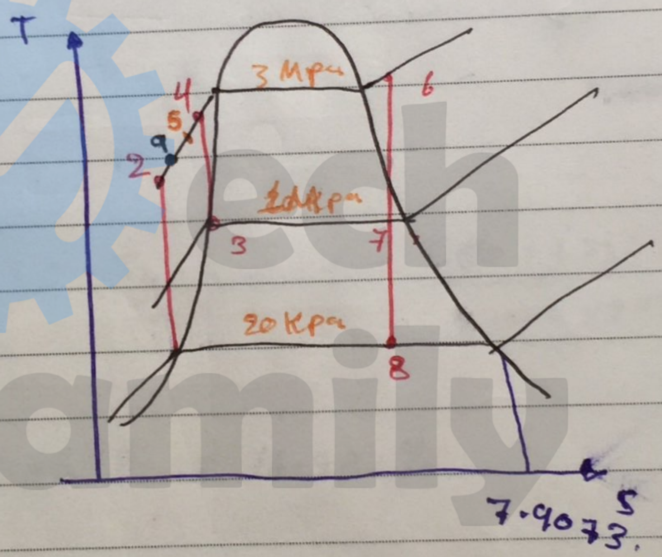
1 2 3 4 6 9

✓

5 7 8

??





point [1] sat Liquid @ 20Kpa

$h_{f_1} = 251.42$, $v_{f_1} = 0.001017$, $s_{f_1} = 0.832$

$s_{fg} = 7.0752$, $s_g = 7.9073.$

point [2] since $s_2 = s_1$,

$$\cancel{(1-Y)}(h_2 - h_1) = \cancel{(1-Y)}\, v_{f_1}(P_2 - P_1).$$

$$h_2 = h_1 + v_{f_1}(\underbrace{\overset{3000}{P_2} - \overset{20}{P_1}}_{\text{Kpa}}) = 254.45 \ \frac{KJ}{Kg}$$

✓

No.

point [3] sat. Liquid @ 1 Mpa

$h_g = h_{f_3} = 762.51$ , $v_{f_3} = 0.001127$ , $s_{f_3} = 2.1381$

$s_{fg_3} = 4.447$ , $s_g = 6.585$ , $h_{fg} = 2014.6$

point [4] $s_3 = s_4$ ,

$$\cancel{Y}(h_4 - h_3) = \cancel{Y}\, v_{f_3} (\underbrace{P_4}_{3000\ Kpa} - \overset{1000\ Kpa}{P_3})$$

$$h_4 = h_3 + v_{f_3}(P_4 - P_3)$$
$$= 764.764.$$

point [6] 3 Mpa , 350°C } S.H

$h_6 = 3116.1$ , $s_6 = 6.745.$

point [7] $s_7 = s_6 = 6.745 > s_g|_{1 Mpa} \longrightarrow$ S.H

| T | h | s |
|---|---|---|
| 200 | 2828.3 | 6.6956 |
| $T_7$ | $h_7$ | 6.745 |
| 250. | 2943.1 | 6.9265 |

$h_7 = 2852.86$

$T_7 = 210.69$

No.

point $\boxed{8}$ since $s_8 < s_g|_{20\,kPa}$ ∴ wet mix.

$$x_8 = \frac{s_8 - s_{f_1}}{s_{fg}} = 0.8357$$

$$\therefore h_8 = 2221.67 \ \frac{KJ}{Kg}$$

point $\boxed{5}$ $$Y = \frac{h_4 - h_2}{h_7 - h_2}$$

$$= 0.1955$$

$$h_5 = (1-Y)\, h_3 + Y\, h_4$$

$$= 763$$

$$q_h = h_6 - h_5 = 2353.15 \ \frac{KJ}{Kg}$$

$$w_p = (1-Y)\,(h_2 - h_1) + Y\,(h_4 - h_3)$$

$$= 2.9 \ \frac{KJ}{Kg} \simeq 3 \ \frac{KJ}{Kg}$$

$$w_T = (h_6 - h_7) + (1-Y)\,(h_7 - h_8)$$

$$= 771$$

No.

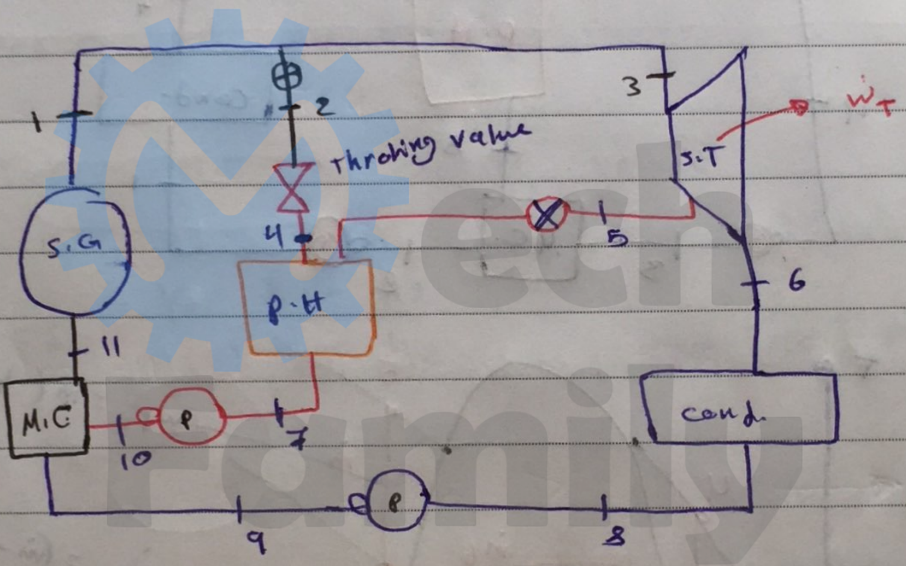
## **R Cogeneration cycle.

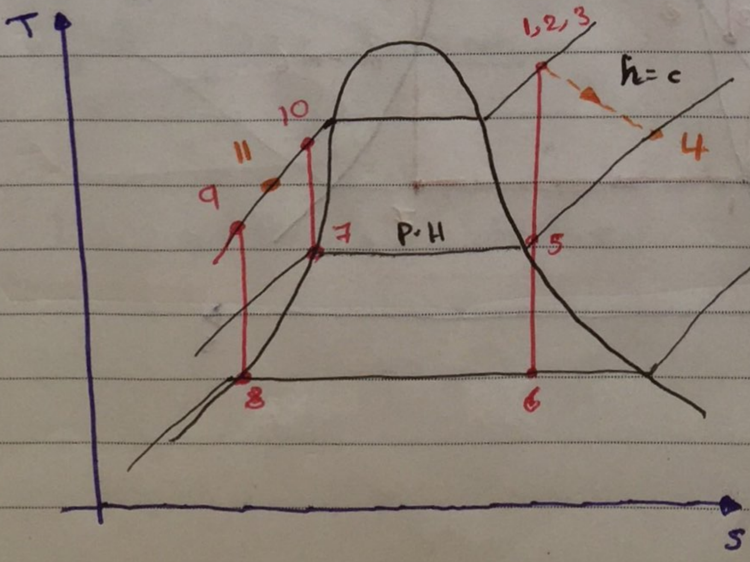
Co

معاً

Steam will be Utilized for
- Electric.
- process heater.

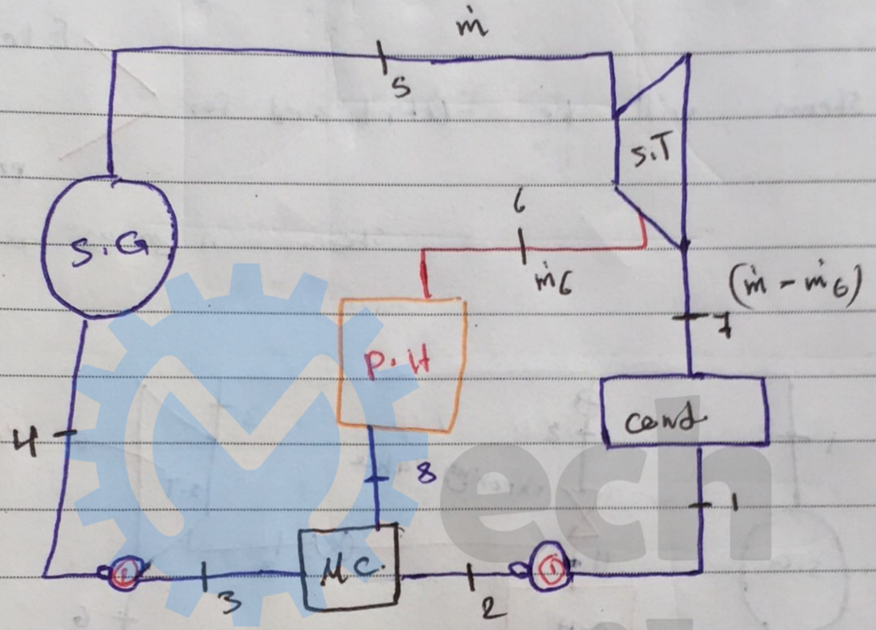
اي صناعة تقوم على ال Steam.

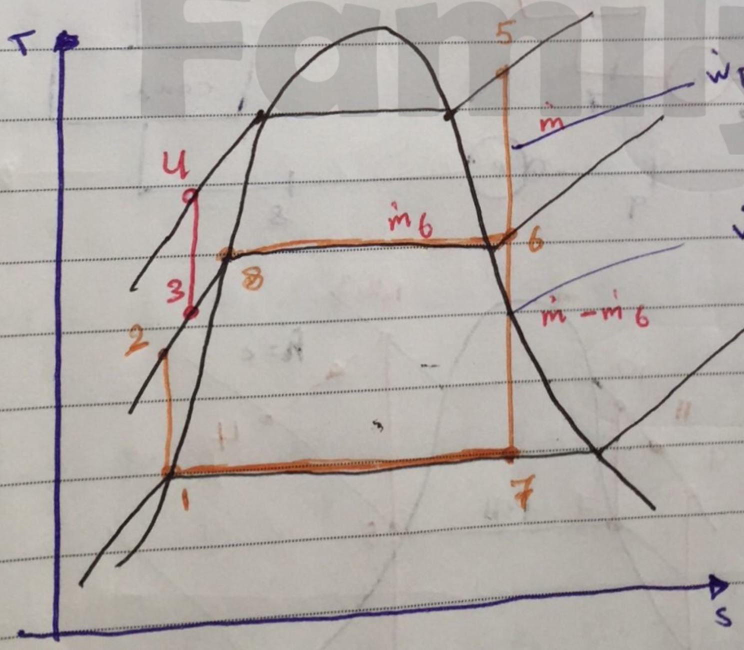




## *** Cogeneration cycles ***

## CH # 11 : Refrigeration cycles.





$\dot{w}_{T_1} = \dot{m}(h_5 - h_6)$

$\dot{w}_{T_2} = (\dot{m} - \dot{m}_6)(h_6 - h_7)$

No.

$\dot{Q}_H = \dot{m}(h_5 - h_4)$

$\dot{Q}_L = (\dot{m} - \dot{m}_6)(h_7 - h_1)$

$\left[\ \dot{Q}_{P.H} = \dot{m}_6 (h_6 - h_8)\right.$

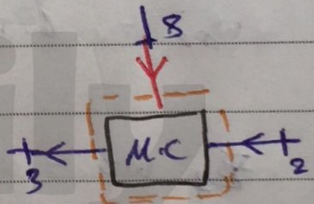
$\dot{W}_T = \dot{m}(h_5 - h_6) + (\dot{m} - \dot{m}_6)(h_6 - h_7)$

$\dot{W}_{P1} = (\dot{m} - \dot{m}_6)(h_2 - h_1)$

$\dot{W}_{P2} = \dot{m}(h_4 - h_3)$

Take M.C as control volume.

$$\frac{\dot{m}_6}{\dot{m}} = Y = \frac{h_3 - h_2}{h_8 - h_2}$$



Turbine cascade.

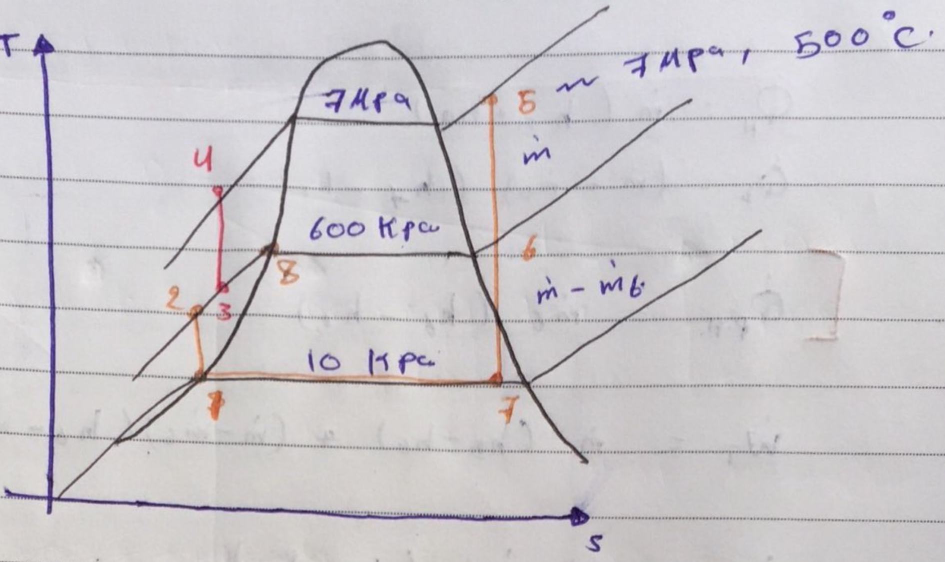
$$\boxed{\epsilon_u = \frac{\dot{Q}_{P.H} + \dot{W}_{net}}{\dot{Q}_H}}$$

utilization factor

prob. 10.67

$Y = 0.25$

$\dot{m} = 30 \frac{kg}{s}$



$W_{P_1} = 0.6 \frac{KJ}{Kg}$

$W_{P_2} = 6.56 \frac{KJ}{Kg}$

~~X~~ $W_P = (h_4 - h_3) + (1-Y)(h_2 - h_1)$
$=$

$X_7 = 0.82.$

$6 \Rightarrow$ S.H

$E_u = 0.524.$

$\dot{Q}_{P.H} = \dot{m}_6 (h_6 - h_8)$
$= 15782$ KW

$\dot{Q}_H = \dot{m}(h_5 - h_4) = 92788$ KW

$\dot{Q}_L = (\dot{m} - \dot{m}_6)\ (h_7 - h_1)$

$= 44140.$

$\dot{W}_T = 33074.625$

$\dot{W}_{P_2} = 211.2.3$

$\dot{W}_{P_1} = 13.467$

[illegible]

point $\boxed{1}$

$h_1 = h_f = 191.81$

$s_1 = s_f = 0.6492$

$s_{fg_1} = 7.4996$

$v_{f_1} = 0.00101$

point $\boxed{2}$ $P_2 = 600\text{kPa}$

$h_2 = v_{f_1}(P_2 - P_1) + h_1$

$= 192.4059$

point $\boxed{5}$

$h_5 = 3411.4$

$s_5 = 6.8$

$s_5 = s_6 = s_7$

point $\boxed{8}$

$h_8 = h_{f_8} = 670.38$

$s_8 = s_{f8} = 1.9308$

$s_{fg_8} = 4.8285$

$h_{fg_8} = 2085.8$

$v_{f8} = 0.001101$

point $\boxed{3}$

$Y = \frac{\dot{m}_6}{\dot{m}} \Rightarrow \dot{m}_6 = 7.5 \frac{\text{Kg}}{s}$

$Y = \frac{h_3 - h_2}{h_8 - h_2} \Rightarrow h_3 = ~~311.89~~$

~~[illegible]~~

$311.899$

point $\boxed{4}$

$h_4 = v_{f_3}(P_4 - P_3) + h_3$

~~= 313.44~~ $= 318.913$

point $\boxed{7}$ 10 KPa, $s_7 = 6.8$ (wet mix

$s_7 = s_{f_1} + x_7\ s_{fg_1}$

$\Rightarrow x_7 = 0.82015$

$h_7 = h_{f_1} + x_7\ h_{fg_1} = 2153.69$

point $\boxed{6}$ $s_6 = s_5 = 6.8$

$P_6 = 600\text{ Kpa}$

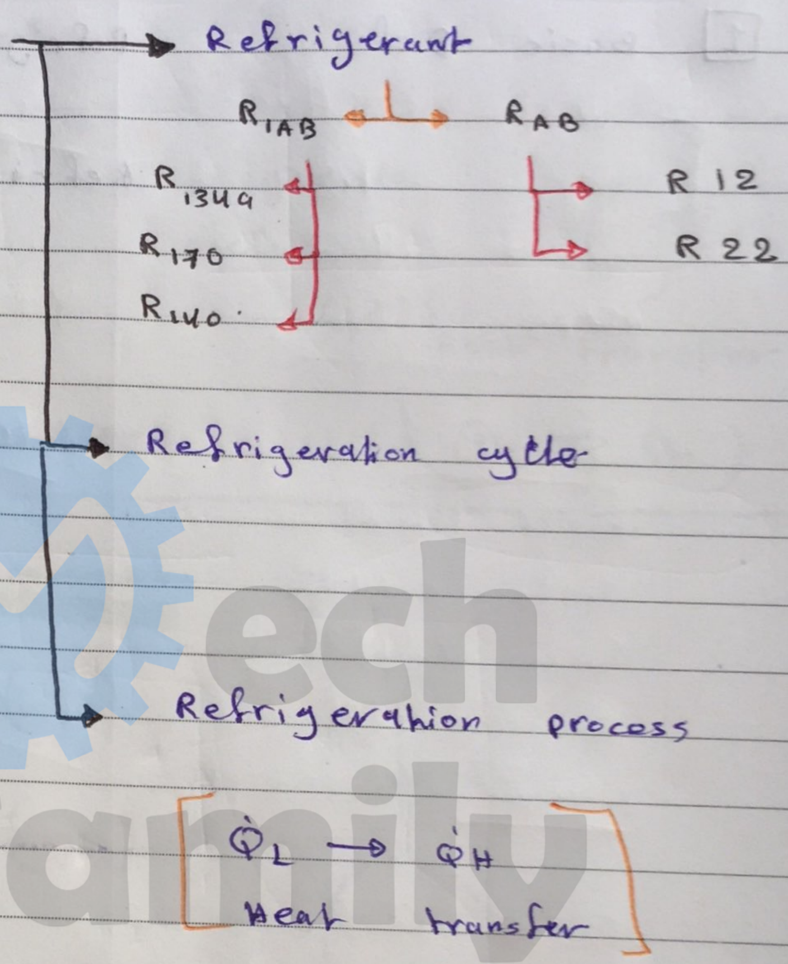
super heated Vapor

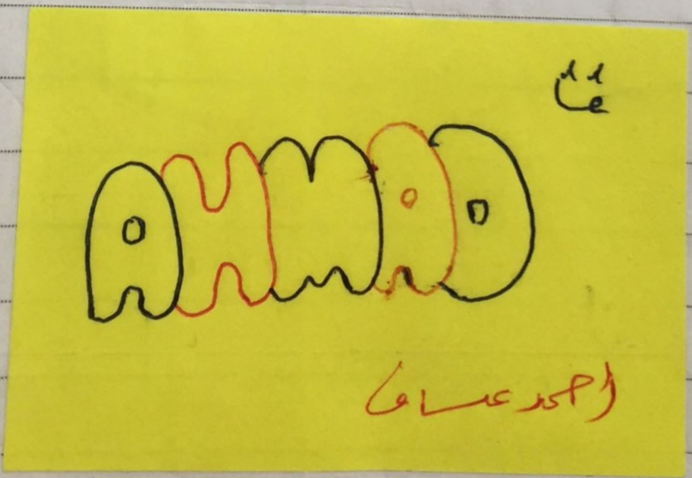
$h_6 = 2774.58$

No.

## CH III : Refrigeration cycles.

### 1 Basic Def



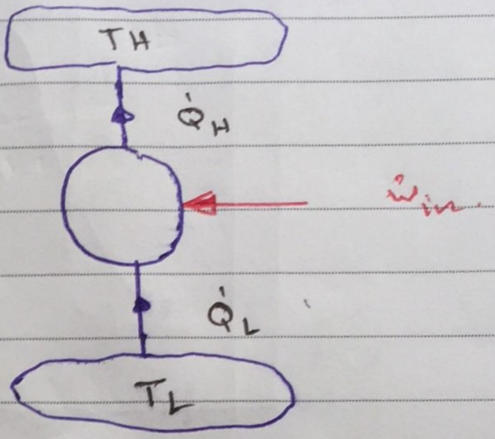


No.

→ Clausius statement :

Refrigeration ( $\dot{Q}_L$ )

Heat pump ( $\dot{Q}_H$ )



$$COP = \frac{\text{Desired output}}{\text{Required input } (\dot{W}_{in})}$$

cooling capasity (tonne)

$h_{fs} = 303.85 \ \frac{KJ}{kg}.$ for water

$h_{fs}$ : latent heat of Fusion

1Btu = 1.055 KJ

$$1 \text{ tonne} = \frac{1000 \text{ kg} \times 303.85}{24 \text{ hrs}}$$

= 12660 KJ /hr

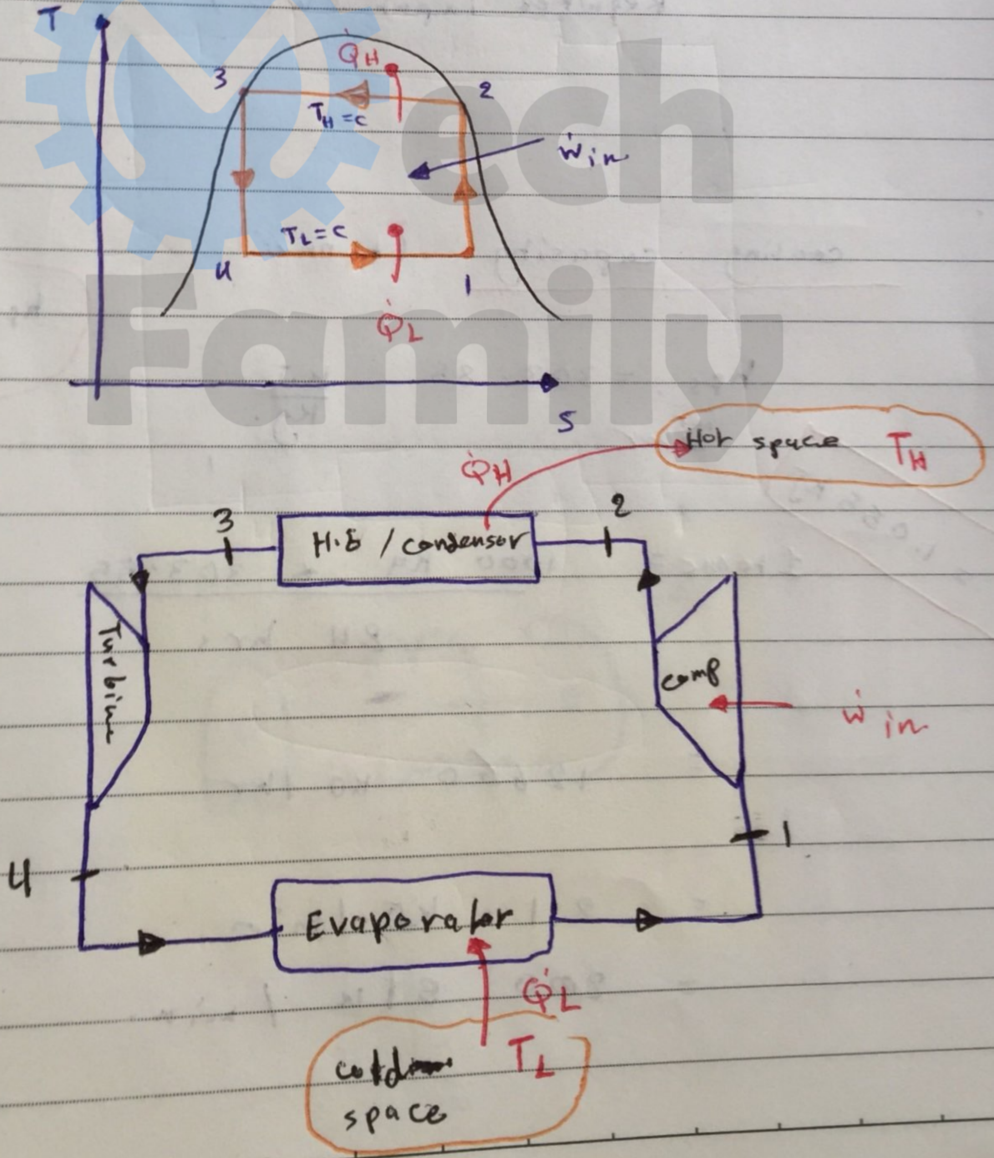
= 211 KJ /min

= 200 Btu /min.

$$\text{Cooling capacity} = \frac{\dot{m}_R \; \dot{Q}_L \times 3600}{\dot{m}_w \times h_{fs} \times \frac{1}{24}}$$

$$= \frac{\dot{m}_R \; \dot{Q}_L \times 3600}{12660}$$

## Carnot Ref. cycle :-



→ $\boxed{1}$ compressor inlet is wet mixture.

→ $\boxed{3}$ turbine inlet is saturated liquid.

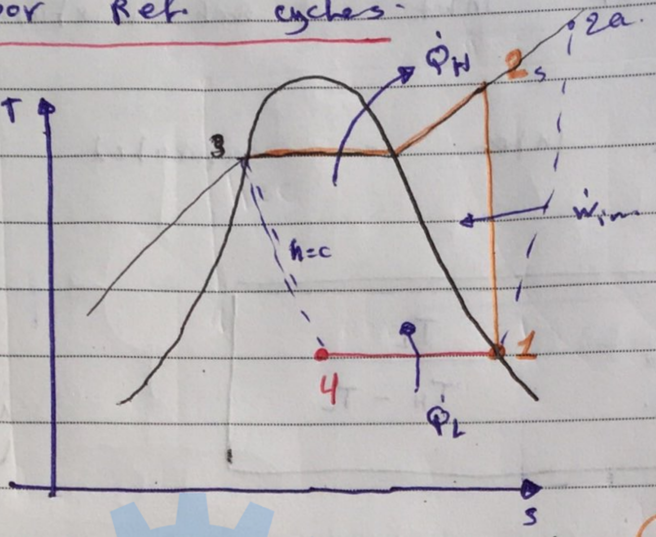
$$\boxed{COP_{\substack{mech\\Ref.}} = \frac{T_L}{T_H - T_L}}$$

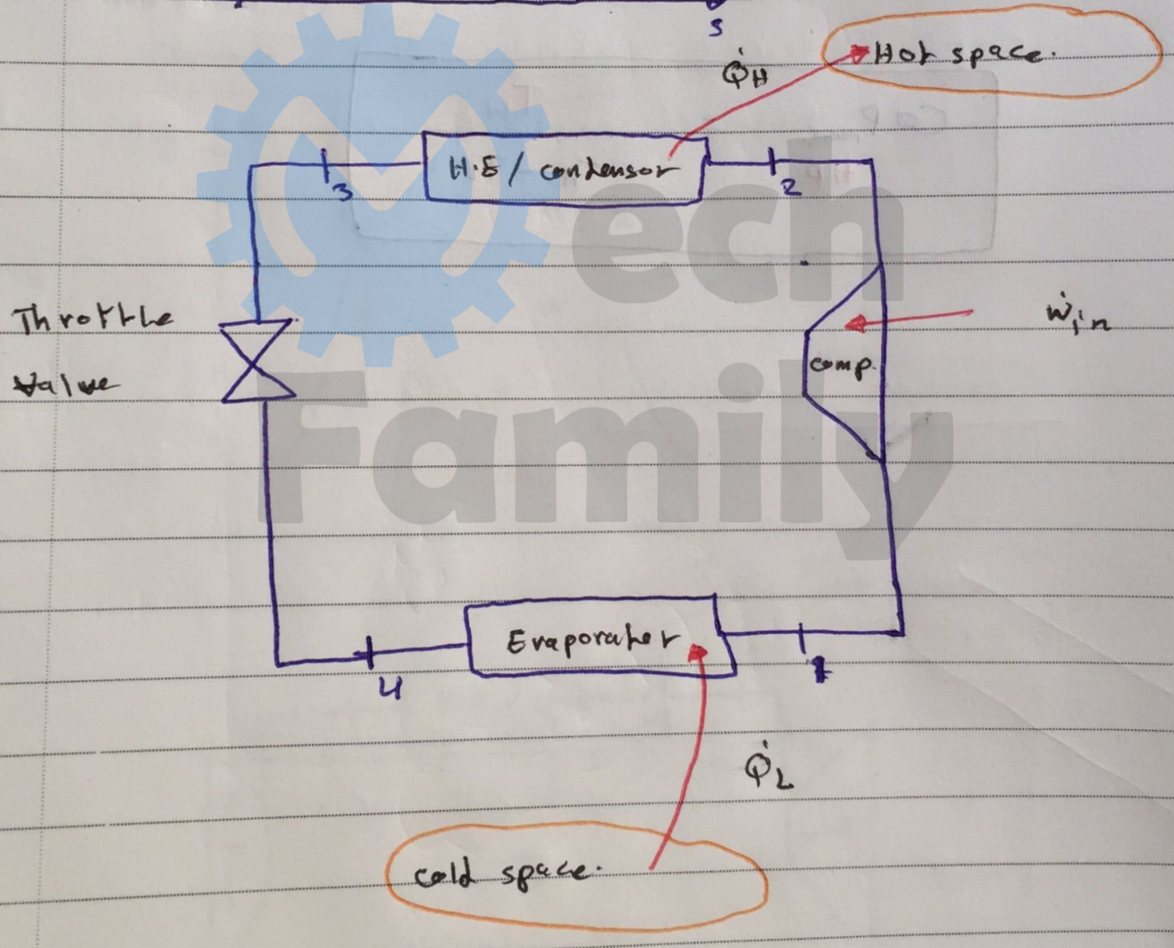
$$\boxed{COP_{\substack{mech.\\HP}} = \frac{T_H}{T_H - T_L}}$$

No.

comp.

## Vapor Ref. cycles.





$\dot{W}_c = \dot{m}_R \ (h_2 - h_1)$

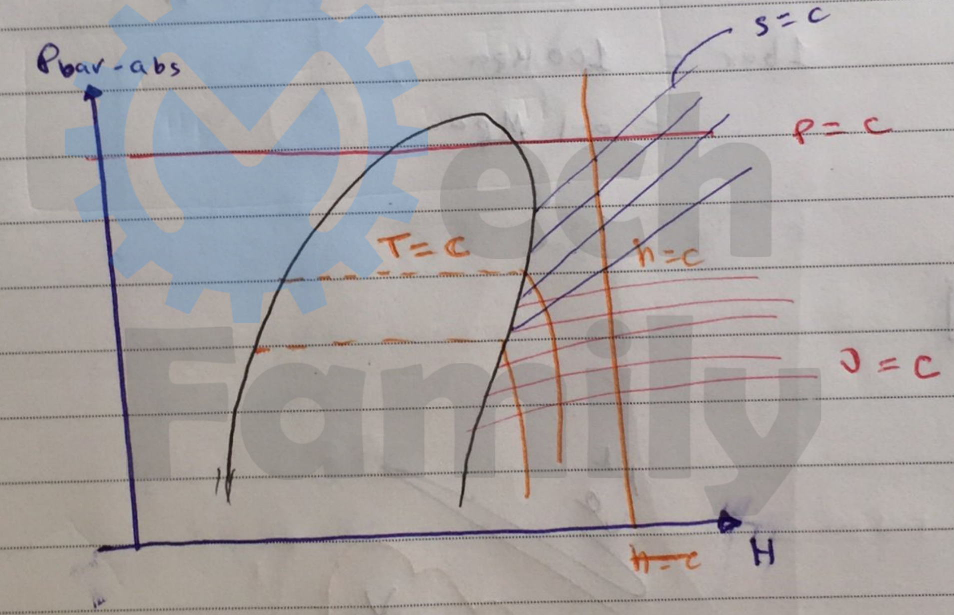
$\dot{Q}_L = \dot{m}_R \ (h_1 - h_4)$

No.

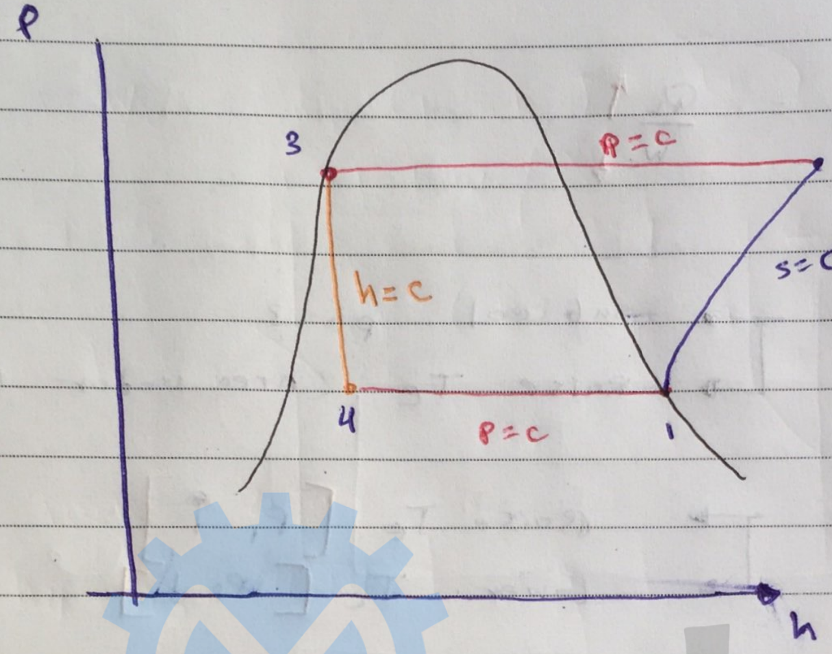
$COR_R = \frac{\dot{Q}_L \uparrow}{\dot{W}_c \downarrow}$

$Q_L \uparrow$ → sub cool pb 3
→ Raise Te (Area under 4-1)

$\dot{W}_{in} \downarrow$ → Raise Te [$P_1 \uparrow$]
→ Lower $T_c$ [$P_2 \downarrow$]



No.



1bar = 100 Kpa

= 0.1 Mpa

**Ex. 11.1**

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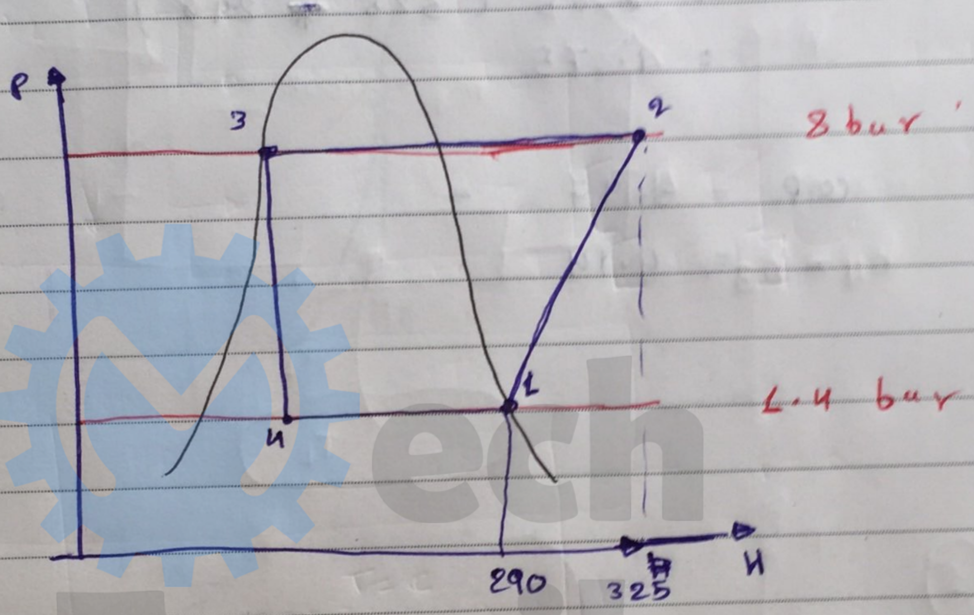
No.

Ex 11.1 $\dot{m}_R = 0.05$ kg/s.

$P_3 = P_2 = 0.8$ Mpa $= 8$ bar.

$P_1 = P_4 = 0.14$ Mpa $= 1.4$ bar



$h_3 = 145$

$h_1 = 290$

$h_2 = 325$

$h_4 = 145$

| | From table R-134a. A-11 | chart. |
|---|---|---|
| 1 | 239.19 $h_1 = h_g @ 0.14$ Mpa | 290 |
| 2 | 275.4 | 325 |
| 3 | $h_3 = h_4 = 95.48 = h_f$ @0.8Mpa | 145 |
| 4 | | |

No.

$\dot{W}_c = \dot{m}_R (h_2 - h_1)$

$= 1.81$ kW

$= 0.05 (325 - 290)$

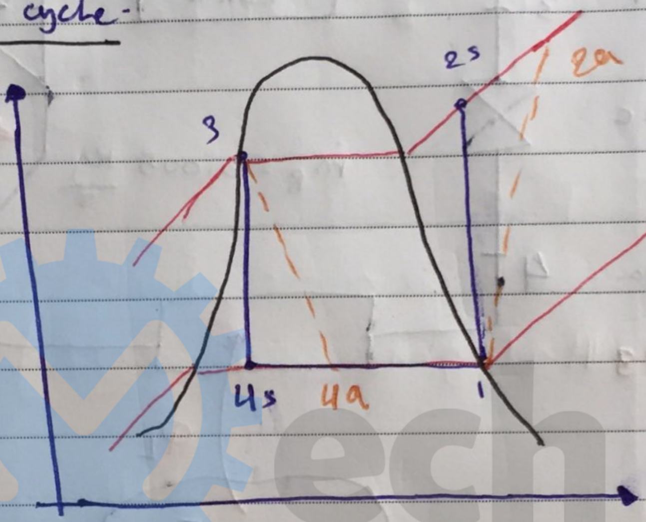
$= 1.75$

COP $= 3.97$

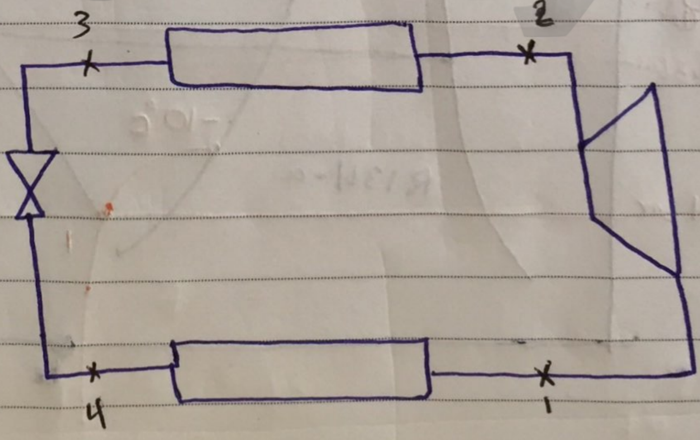
$= 4.14$

ASHRAE

Actual cycle-

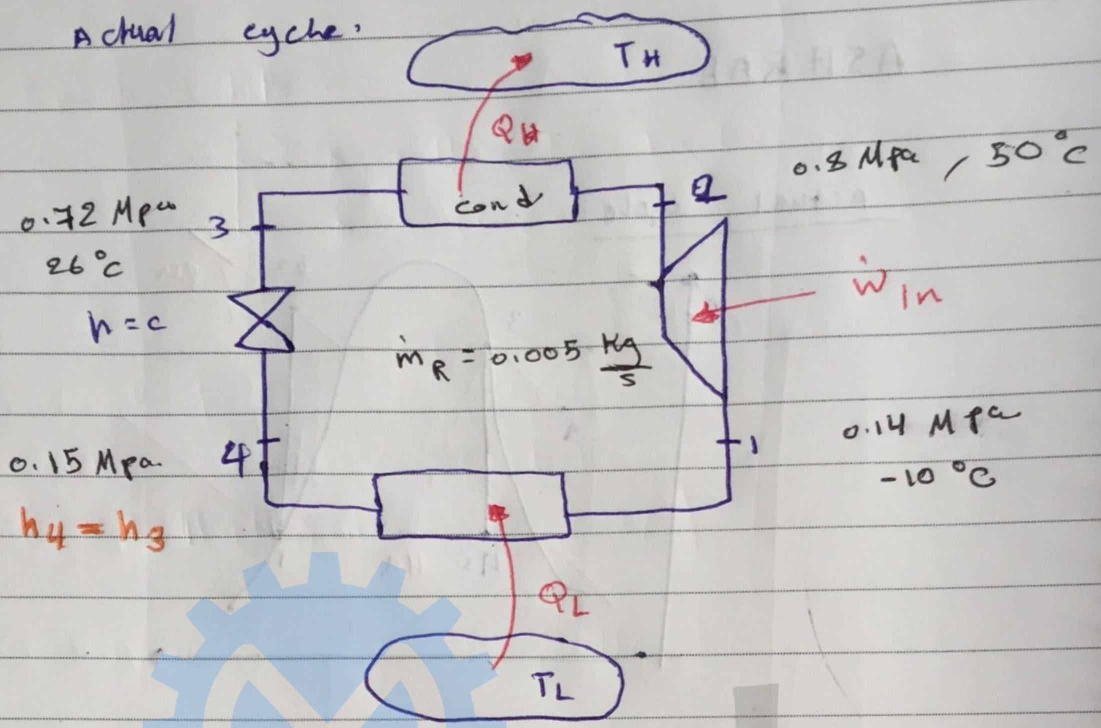


$$\eta_{cs} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

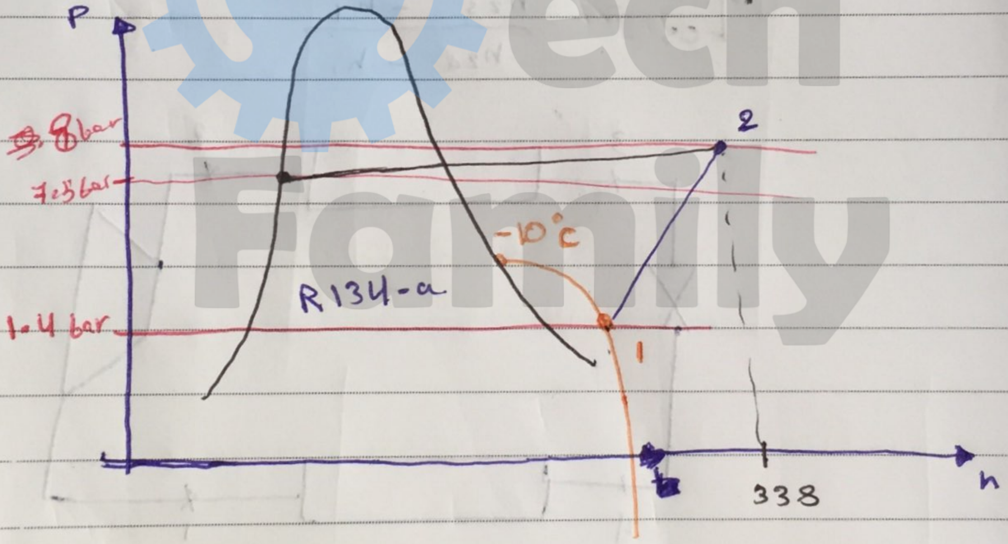


No.

Ex 11-2 Actual cycle.



sol. 1



$h_1 = 295$

$h_2 = 338$

$h_3 = 136$

$= h_4$ #

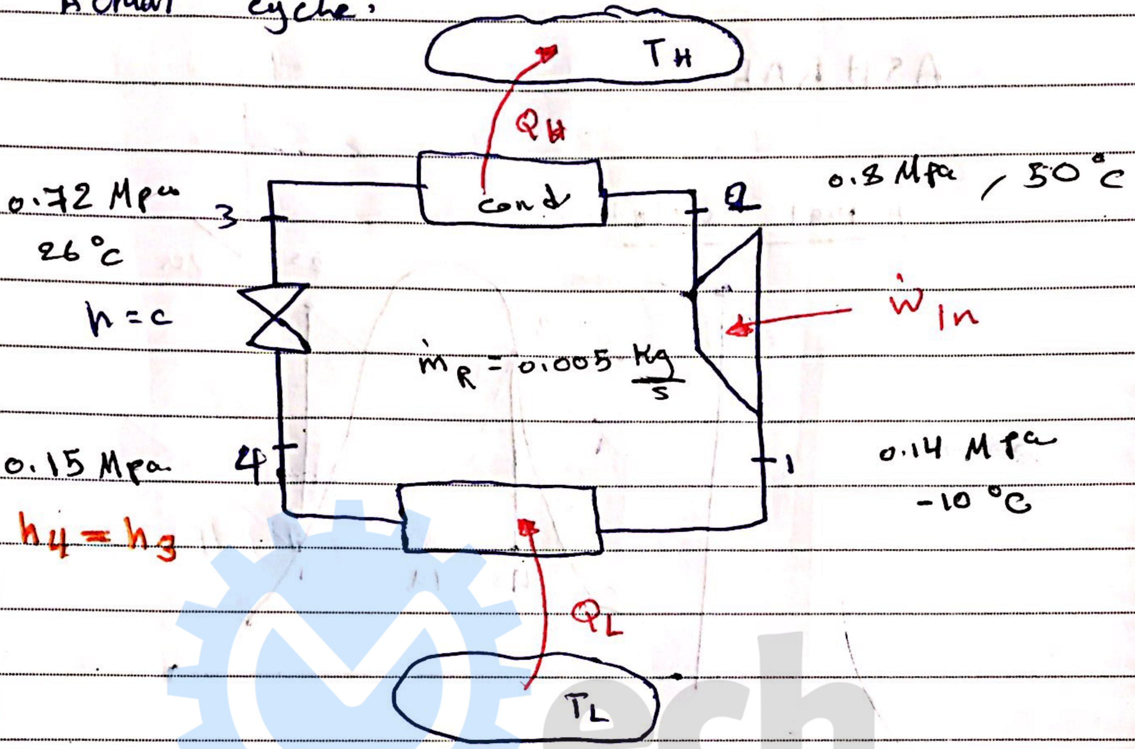
بالجداول

$h_1 = 246.37$

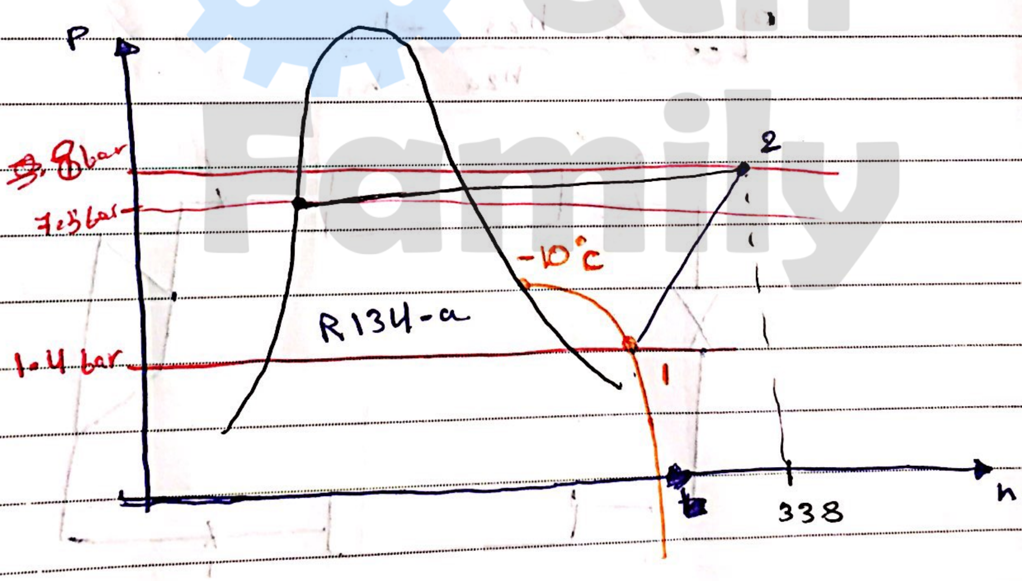
$h_2 = 286.71$

No.

**Ex 11-2** Actual cycle.



sol. 1



$h_1 = 295$

$h_2 = 338$

$h_3 = 136$

$= h_4$ #

بالجداول

$h_1 = 246.37$

$h_2 = 286.71$

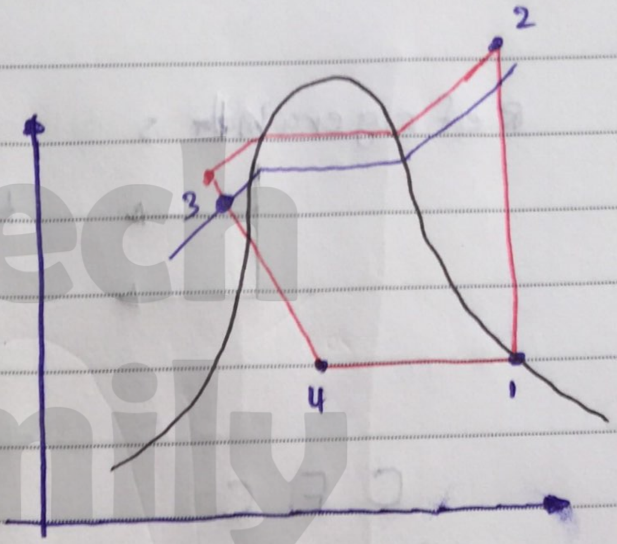
130

No.

الرسمة لفتح الجداول

$h_{f @ 26^\circ C} = h_3$

$= 87.83$



No.

Refrigerants

- How to read
- properties

C F C

Chloro - Flourow - carbon

Halogenes

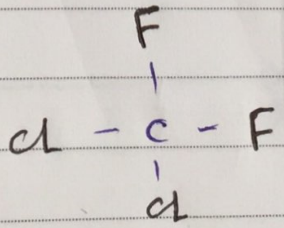
$CH_4$ $C_2H_6$

$R_{ab}$ $R_{1ab}$

a - 1 = H Not replaced

b = F present

$R_{\underset{a}{1}\underset{b}{2}}$



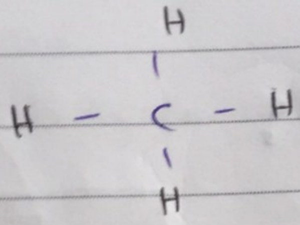
H = 0

F = 2

c H cl F

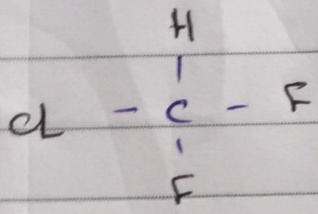
No.

$R_{50}$
ab



$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & H \\ & & | & & \\ & & H & & \end{array}$

$R_{22}$
ab

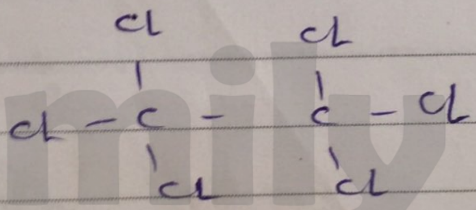


$\begin{array}{ccccc} & & H & & \\ & & | & & \\ Cl & - & C & - & F \\ & & | & & \\ & & F & & \end{array}$

$R_{10}$
ab

$\boxed{CCl_4}$

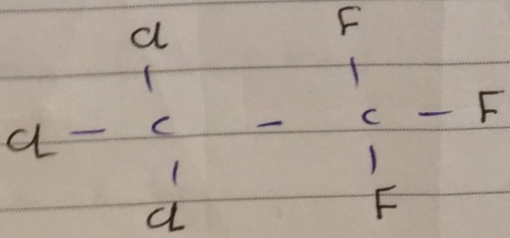
$R_{110}$
1ab



$\begin{array}{ccccccc} & & Cl & & Cl & & \\ & & | & & | & & \\ Cl & - & C & - & C & - & Cl \\ & & | & & | & & \\ & & Cl & & Cl & & \end{array}$

$\boxed{C_2Cl_6}$

$R_{113}$
1ab



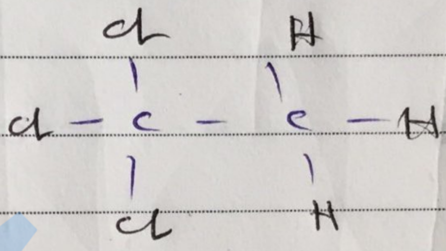
$\begin{array}{ccccccc} & & Cl & & F & & \\ & & | & & | & & \\ Cl & - & C & - & C & - & F \\ & & | & & | & & \\ & & Cl & & F & & \end{array}$

$\boxed{C_2Cl_3F_3}$

No.

$R_{134}a_s$ $R_{140}$

$R_{140}$



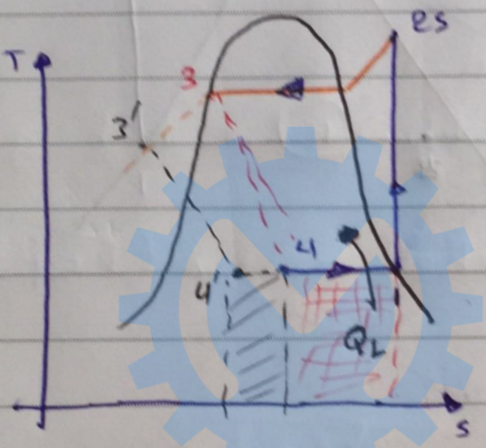
$\boxed{C_2H_3Cl_3}$

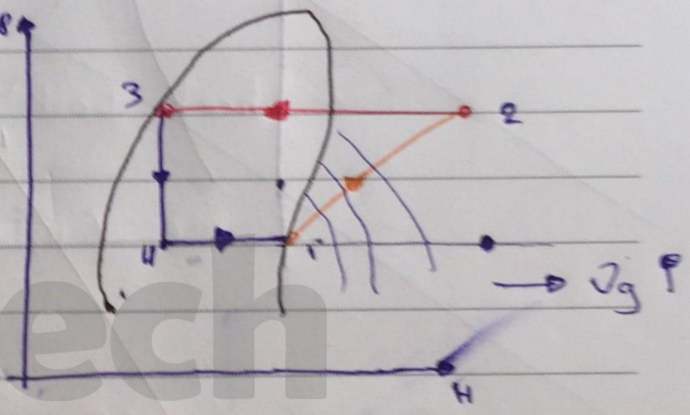
No.

11.5 - Innovative Ref cycles.

* cascade Ref. cycle.

- Gas Ref. cycle
- Ammonia Absorption cycle.





$$\uparrow COP_R = \frac{Q_L \uparrow}{W_c \downarrow}$$

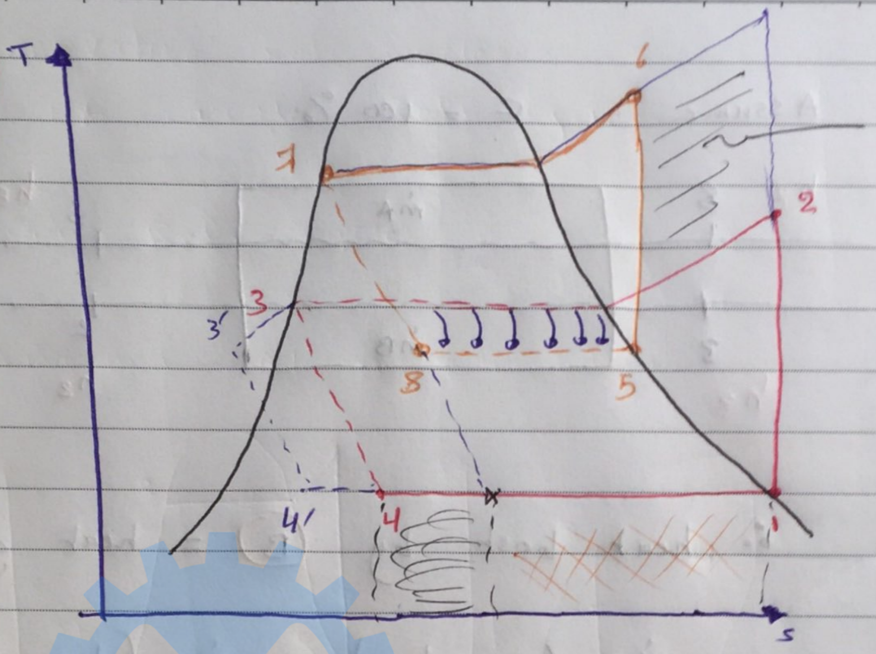
1) sub cool pt 3. $x \downarrow$

$$\dot{Q}_L = \dot{m}_R (h_1 - h_4)$$

$$h_4 = h_f + x\, h_{fg}$$

No.

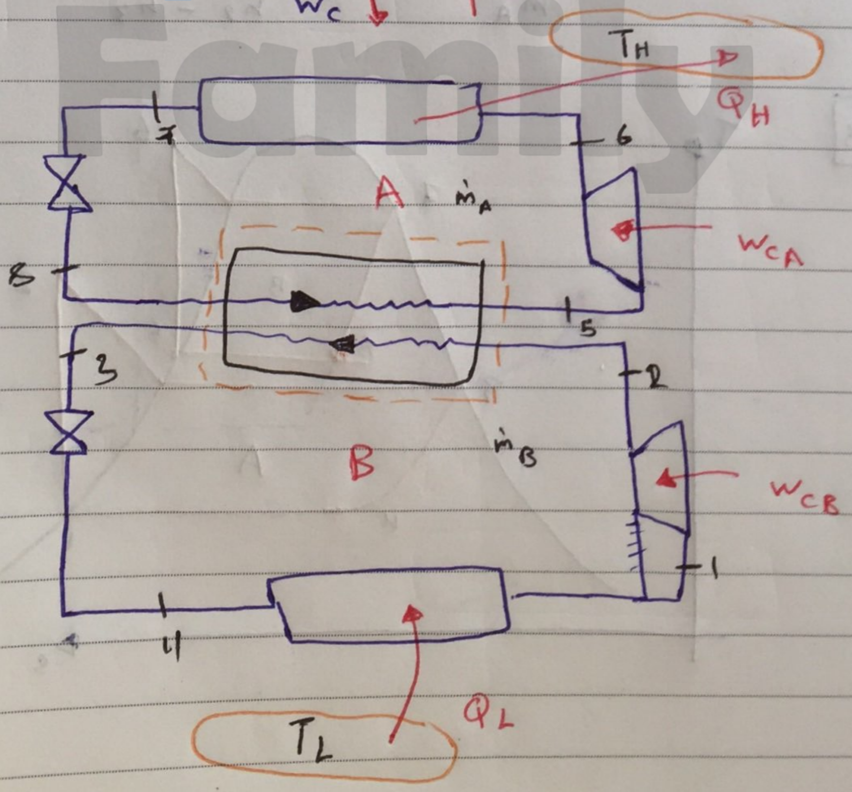
cascade
Ref
cycle



W
اللي وفرنا

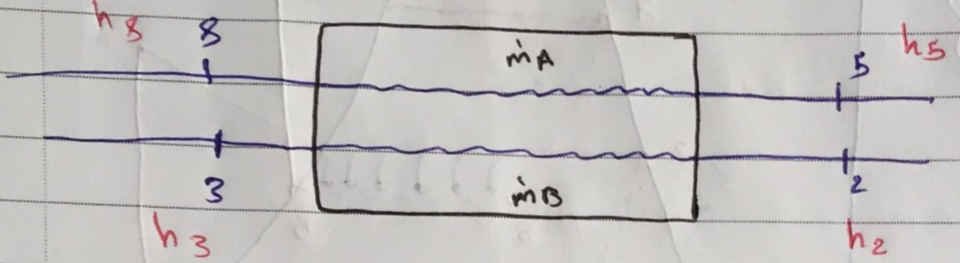
$$W_s = \int v \, dP$$

$$COP = \frac{Q_L \uparrow}{W_c \downarrow} \quad \uparrow$$



No.

Assume $\epsilon = 100\ \%$

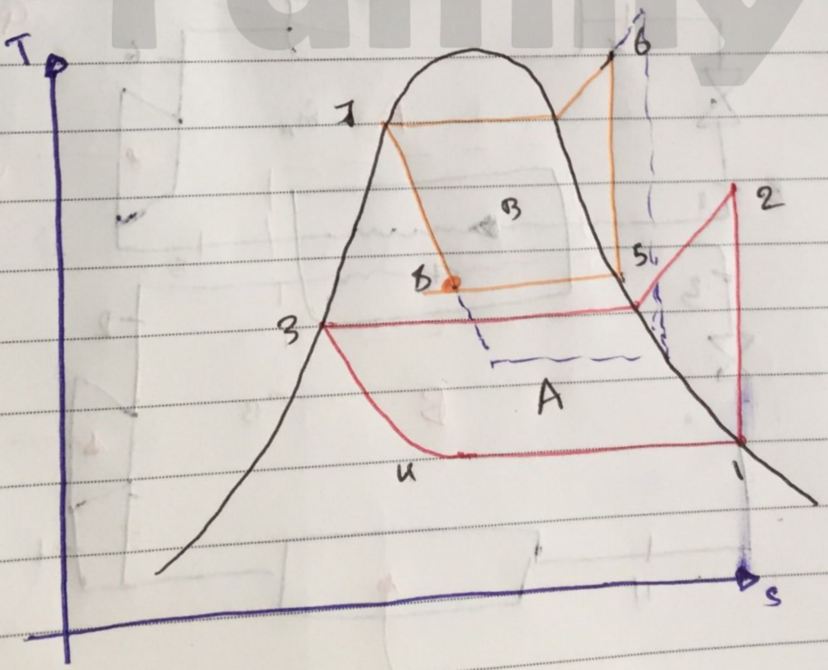


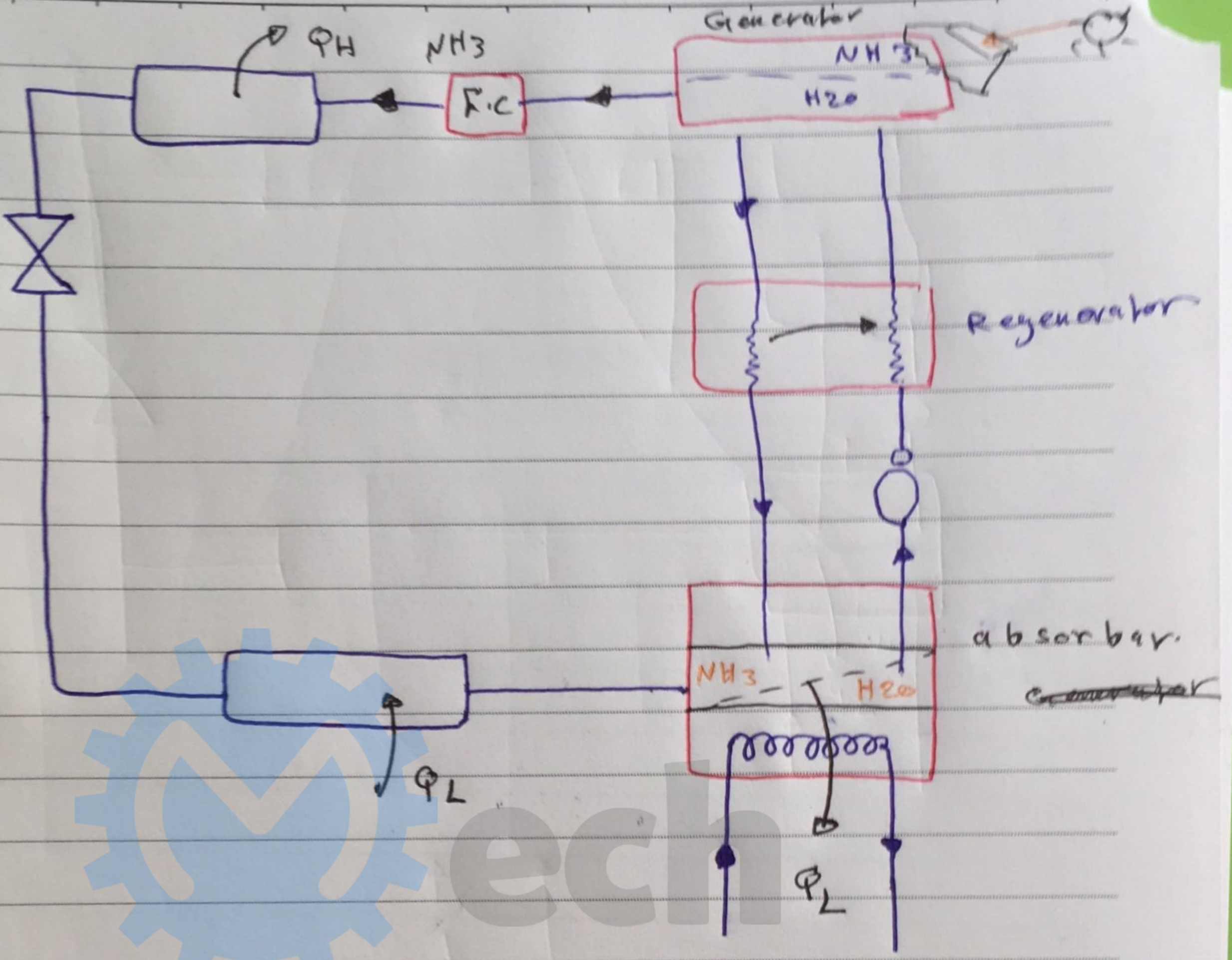
∴ heat lost by (B) = heat gained by (A)

$$\dot{m}_B\ (h_2 - h_3) = \dot{m}_A\ (h_5 - h_8)$$

$$\therefore \quad \frac{\dot{m}_B}{\dot{m}_A} = \frac{h_5 - h_8}{h_2 - h_3}$$

**Ex 11-3**




Generator
NH3
H2O
QH
NH3
F.C
Regenerator
absorbar.
~~Generator~~
NH3
H2O
QL
QL

$$\uparrow COP_R = \frac{\dot{Q}_L \uparrow}{\dot{W}_c \downarrow}$$

$$\uparrow \dot{Q}_L = \boxed{\uparrow \dot{m}_R} \; \boxed{(\uparrow h_1 - h_4^{\downarrow})}$$

$$h_4 = h_f + x_4 \, h_{fg}$$

$$\downarrow \dot{W}_c = \boxed{\downarrow \dot{m}_R} \; (\downarrow h_2 - \boxed{h_1^{\uparrow})} \downarrow$$

$$h_1 = h_g$$

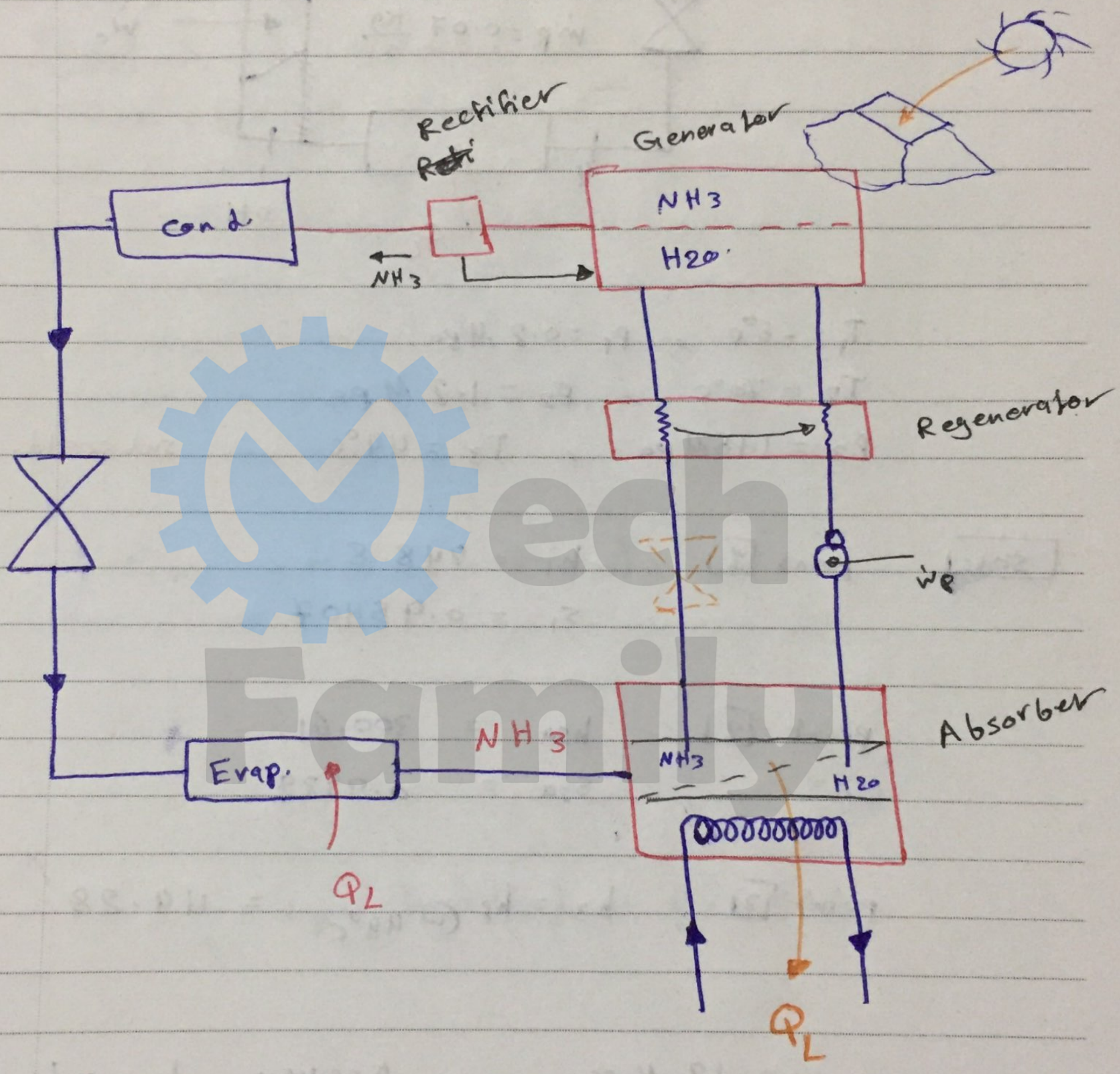
$h_2 \downarrow$ $h_4 \downarrow$ يتبقى حلين فقط

$\boxed{1}$ Either Reduce $x_4$ } Both
$\boxed{2}$ Reduce $T_4$

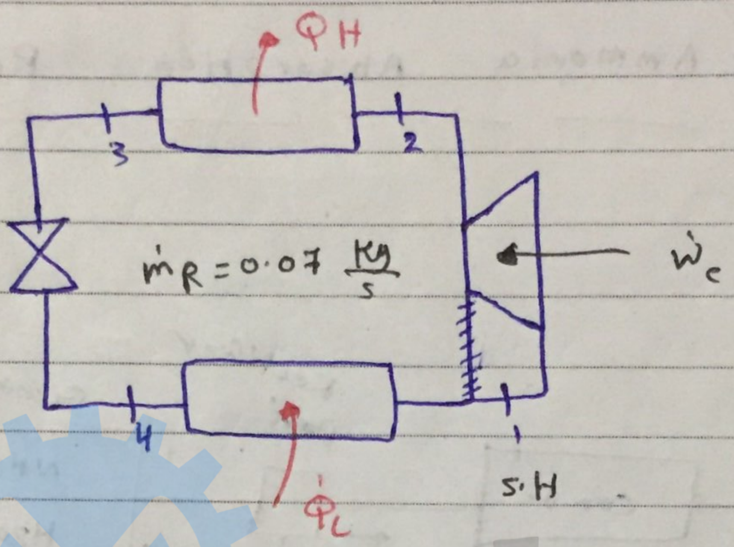
$\dot{W}_c \downarrow$ → Multistage comp.
→ Cascade Ref

No.

# Ammonia Absorption Ref. cycle.



prob. 11.16



$T_1 = -5°C$ , $P_1 = 0.2\ Mpa$ ,

$T_2 = 70°C$ , $P_2 = 1.2\ Mpa$

$P_3 = 1.15\ Mpa$ , $T_3 = 44°C$ sub cooled

sol. point [1] $h_1 = 248.8$

$s_1 = 0.95407$

point [2] $h_{2a} = 300.61$

$s_{2a} = 0.9939$

point [3] $h_3 = h_f @ 44°C = 114.28$

$P_4 = 0.12\ Mpa$ Assume $h_4 = h_3$

No.

$$\eta_{cs} = \frac{h_{2s} - h_1}{h_{2a} - h_1} = 74\%$$

$\boxed{At}$ $S_{2s} = 0.95407 = S_1$

$P_2 = 1.2$ MPa

$\Longrightarrow h_{2s} = 287.21$

$\dot{W}_{ca} = \dot{m}_R (h_{2a} - h_1)$

$= 3.62$ KW.

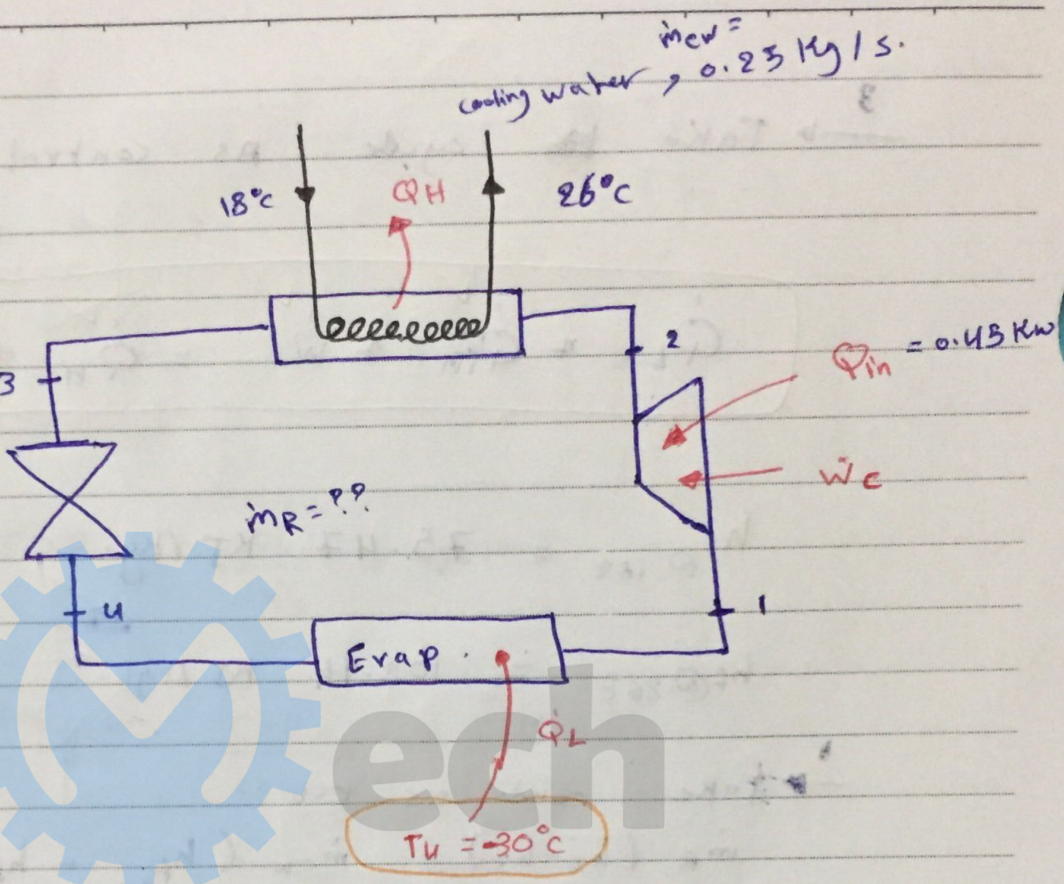
$\dot{Q}_H = \dot{m}_R (h_2 - h_3)$

$COP = 2.6$.

$\dot{Q}_L = \dot{m}_R (h_1 - h_4) = 9.43$ KW.

No.

11.17



$P_1$ = 60 Kpa , $T_1$ = -34°c

$P_2$ = 1.2 Mpa , $T_2$ = 65°c

$P_3$ = 1.2 Mpa , $T_3$ = 42°c , sub coold.

$\boxed{\text{sol.}}$ point $\boxed{2}$ $h_{2a}$ = 295.16 KJ/Kg

$s_{2a}$ =

point $\boxed{1}$ $h_1$ = 230.03 KJ/Kg

point $\boxed{3}$ $h_3 = h_{f@42°c}$ = 111.23 KJ/Kg

point $\boxed{4}$ $h_3 = h_4$ = 111.28 KJ/Kg

No.

3 → Take cycle As control volume

$$\boxed{\dot{Q}_L + \dot{Q}_{in} + \dot{W}_c = \dot{Q}_H} \Rightarrow$$

$h_{f@18°c} = 75.47$ KJ/Kg.

$h_{f@26°c} = 108.94$ KJ/Kg.

1 → Take cond. as C.V :-

$\dot{m}_R (h_2 - h_3) = \dot{m}_{cw} (h_{f_{out}} - h_{f_{in}})$

∴ $\dot{m}_R = 0.0455$ Kg/s.

2 → take comp. as C.V :-

$\dot{m}_R h_1 + \dot{W}_c + \dot{Q}_{in} = \dot{m}_R h_2$

$\dot{W}_c = \dot{m}_R (h_2 - h_1) - \dot{Q}_{in}$

$= 2.513$ KW.

No.

$$\dot{Q}_L + 2.513 + 0.45 = \dot{m}_R (h_2 - h_3)$$

$$\Rightarrow \quad \dot{Q}_L = 5.4 \text{ K.W}$$

$$COP_R = \frac{\dot{Q}_L}{\dot{W}_c} = 2.148$$

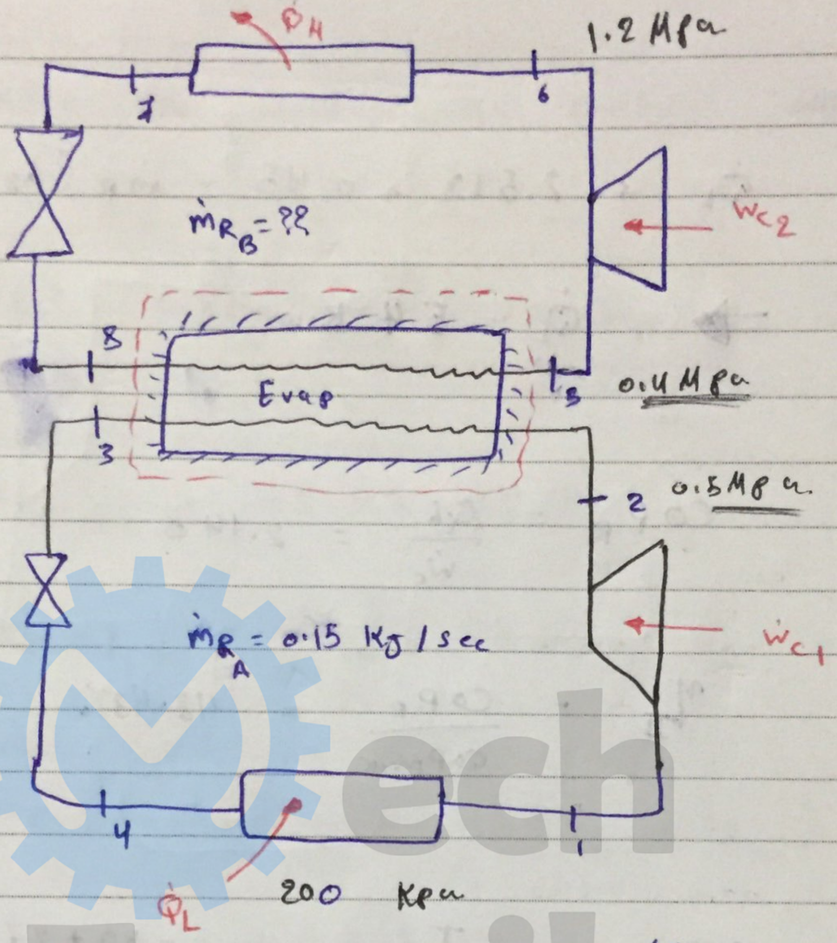
$$\eta_{II} = \frac{COP_R}{COP_{max}} = 42.43\%$$

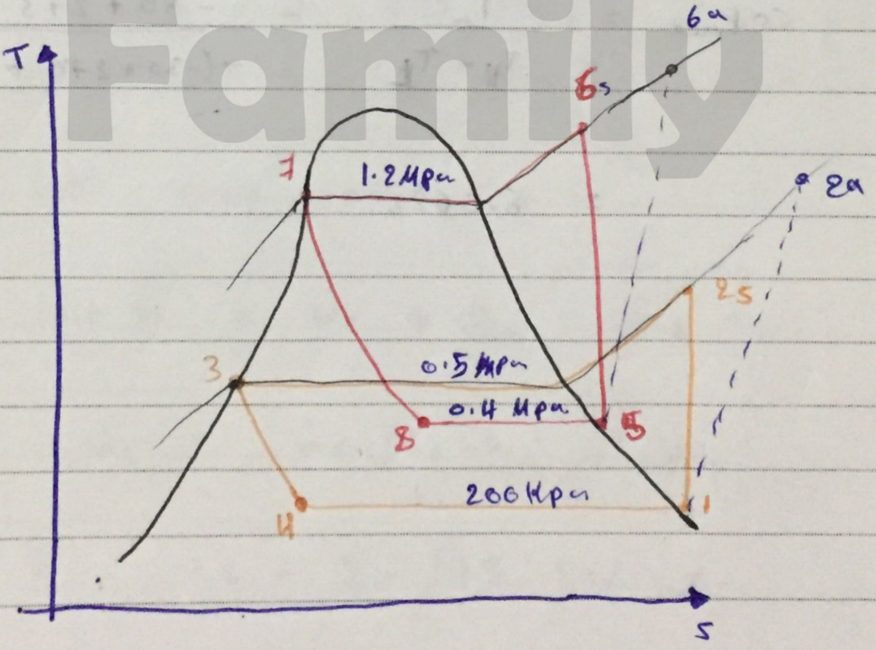
$$COP_{max} = \frac{T_L}{T_H - T_L} = \frac{-30 + 273}{-(-30 + 273) + (18 + 273)}$$

$$= 5.0625$$

No.

57


$Q_H$
1.2 MPa
7
6
$\dot{m}_{R_B}$ = ??
$\dot{W}_{c2}$
8
5
Evap
0.4 MPa
3
2
0.5 MPa
$\dot{m}_{R_A}$ = 0.15 Kg / sec
$\dot{W}_{c1}$
4
1
$Q_L$
200 Kpa


T
6a
6s
7
1.2 MPa
2a
2s
3
0.5 MPa
0.4 MPa
8
5
200 KPa
4
1
s

$\eta_c = 80\ \%$

No.

$h_1 = 244.46$

$s_1 =$

$s_1 = s_2$

$h_{2s} = 263.3$

$h_3 = 73.33$

$h_4 : h_3$

$h_5 = 255.55$

$h_{6s} = 278.33$

$h_7 = 117.77$

$h_8 = h_7 = 117.77.$

$h_{2a} = 268.01$

$h_{6a} = 284.02$

→ take Evap as c.v. :-

$$\dot{m}_{RA} (h_{2a} - h_3) = \dot{m}_{RB} (h_5 - h_8)$$

$$\boxed{\dot{m}_{RB} = 0.212 \text{ kg/s}}$$

$$\dot{Q}_L = \dot{m}_{RA} (h_1 - h_4) = 25.7 \text{ kW}$$

$$\dot{W}_c = \dot{W}_{cA} + \dot{W}_{cB}$$

$$= 9.5 \text{ KW.}$$

$$COP_R = \frac{\dot{Q}_L}{\dot{W}_{cA} + \dot{W}_{cB}} = 2.68$$

$$\dot{X}_{dest} = \dot{m}_R \, T_o \left[ s_f - s_i - \frac{\overset{in}{q_L}}{T_2} + \frac{\overset{out}{q_H}}{T_H} \right]$$

$T_o = T_{H\,atm}$ for Ref.

$T_o = T_L$ for Heat pump.

$$\dot{X}_{\substack{dest\\cycle}} = \dot{W}_{\substack{in\\act.}} - \dot{X}_{Q_L}$$

$$\dot{X}_{Q_L} = \dot{Q}_L \left( \frac{T_o - T_L}{T_2} \right)$$

Q 112

No.

# Properties of Gas Mixtures

$C_{p_{air}} = 1.005$

$C_v = 0.718$

$R = 0.287$

No.

# CH # 13 : Gas Mixture properties

→ How to find mixture properties :-

- → concentration for each component.
- → what are these components.
- → Individual property.

Concentration.

moles (N) mass (m)

mole fraction (Y) نسبة mass fraction ($m_f$)

Molar Analysis (Gravemetric Analysis)

(on volume Basis.)

| | | |
|---|---|---|
| A | $m_A$ | $N_A$ |
| B | $m_B$ | $N_B$ |
| C | $m_C$ | $N_C$ |
| D | $m_D$ | $N_D$ |

total mass $= \left(m_{\substack{mix\\ total}}\right) = m_A + m_B + m_C + m_D$

$$= \sum_{i=1}^{K} m_i$$

totale moles $= \left(N_{\substack{mix\\ total}}\right) = N_A + N_B + N_C + N_D$

$$= \sum_{i=1}^{K} N_i$$

mass fraction A $\left(m_{fA}\right) = \dfrac{m_A}{m_{mix.}}$

$$\boxed{m_{fi} = \frac{m_i}{m_{mix.}}}$$

$$\sum m_f = 1$$

mole fraction A $\left(Y_A\right) = \dfrac{N_A}{N_{mix.}}$

No.

$$\boxed{Y_i = \frac{N_i}{N_{mix.}}}$$

$$\boxed{\sum Y_i = 1}$$

Relation between $m_{fi}$ & $Y_i$ ??

kg / Kmol.

$$m_{fi} = \frac{m_i}{m_{mix}} = \frac{N_i \; M_i}{\sum N_i \; M_i}$$

$$m = N * M$$

لو قسمنا على $N_{mix}$

$$m_{fi} = \frac{Y_i \; M_i}{\boxed{\sum Y_i \; M_i}} \quad \rightarrow M_{mix}$$

$$Y_i = \frac{N_i}{N_{mix}} = \frac{m_i \;/\; M_i}{\sum \left(\frac{m_i}{M_i}\right)} = \frac{m_{fi} \;/\; M_i}{\sum \frac{m_{fi}}{M_i}}$$

اقسم على $m_{mix.}$

No.

$$M_{mix} = \frac{m_{mix}}{N_{mix}}$$

$$= \frac{\sum N_i \; M_i}{N_{mix}}$$

$$\boxed{M_{mix} = \sum Y_i \; M_i}$$

$$\boxed{R_{mix} = \underbrace{R_u}_{\substack{\text{universal} \\ \text{gas} \\ \text{constant}}} / M_{mix}}$$

$$R_u = 8.314 \; \frac{KJ}{Kmol \cdot K.}$$

**Extensive.** إذا فش بكتلم Kg.

H , U , S , m

$$X_{mix} = \sum X_i = \sum \overset{Kg}{m_i} \, \overset{KJ/Kg}{x_i}$$

$$\boxed{m_{mix} = \sum m_i} \qquad = \sum \underset{Kmol}{N_i} \, \underset{KJ/Kmol}{\bar{x}_i}$$

$$H_{mix} = \sum H_i = \sum m_i H_i = \sum m_i \bar{h}_i$$

**Intensive.**

h

$$H_{mix} = m_{mix} h_{mix} = \sum m_i h_i$$

$$\boxed{h_{mix} = \sum m_{fi} \, h_i}$$

$$x_{mix} = \sum m_{fi} \, x_i \qquad KJ/Kg$$

$$\bar{x}_{mix} = \sum Y_i \, \bar{x}_i \qquad KJ/Kmol$$

No.

$$C_{p\,mix} = \sum mf_i \; cp_i$$

$$U_{mix} = \sum mf_i \; u_i$$

$$M_{mix} = \sum Y_i \; M_i$$

Example 13 - 1 631

$O_2$ 3 Kg
$N_2$ 5 Kg
$CH_4$ 12 Kg

Given from table A-1

| component | $m_i$ (Kg) | $M_i$ (Kg / Kmol) | $N_i = \frac{m_i}{M_i}$ | $mf_i = \frac{m_i}{m_{mix}}$ | $Y_i = \frac{N_i}{N_{mix}}$ |
|---|---|---|---|---|---|
| $O_2$ | 3 | 32 | $\frac{3}{32} = 0.094$ | $\frac{3}{20} = 0.15$ | 0.092 |
| $N_2$ | 5 | 28 | $\frac{5}{28} = 0.179$ | $\frac{5}{20} = 0.25$ | 0.175 |
| $CH_4$ | 12 | 16 | $\frac{12}{16} = 0.75$ | $\frac{12}{20} = 0.6$ | 0.733 |
| | 20 $= m_{mix}$ | | $\Sigma = 1.023$ Kmol $= N_{mix}$ | $\Sigma = 1$ | |

$$M_{mix} = \frac{m_{mix}}{N_{mix}} = 19.6$$

No.

$$R_{mix} = \frac{8.314}{19.6} = 0.424 \text{ KJ}/(\text{kg}\cdot\text{K})$$

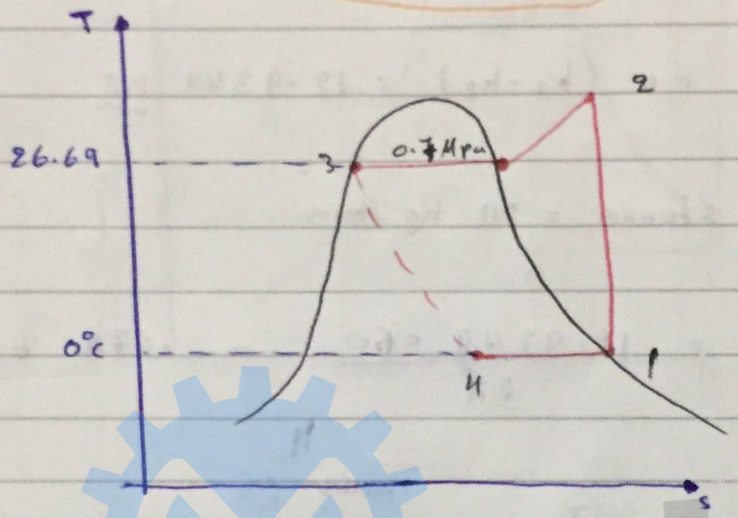
$$K_{mix} = \frac{C_{P mix}}{C_{v mix}} = \frac{\sum m_{f_i} \, C_{P_i}}{\sum m_{f_i} \, C_{v_i}}$$

see prob. 10, 11, 24, 28

40, 50, 52.

Q.1 R-134a

$T_H = 27°c$



$\dot{m}_R = 0.08$ Kg/s

$T_L = -1°c$

① sat. vapor @ 0°c from tables ⇒ $h_1 = h_g$

$= 250.5$

$s_1 = 0.93158$

② $P_2 = P_{sat}$ @ 26.69 = 700 Kpa.

$\therefore h_{2_s} = 268.47$

③ sat. liquid @ 0.7 Mpa $h_3 = h_f = 88.82$ KJ/Kg

$s_3 = s_f = 0.33232$

④ $h_3 = h_4 = 88.82$ KJ/Kg

$h_4 = h_f + x_4 h_{fg}$ ⇒ $x_4 = 0.186$

No.

ⓐ $\dot{W}_c = \dot{m}_R \, (h_2 - h_1) = 1.437$ KW

$\dot{Q}_L = \dot{m}_R \, (h_1 - h_2) = 12.9344 \ \frac{KJ}{s}$

1tonne = 211 KJ /min.

ⓑ $\dot{Q}_L = \frac{12.9344 \times 60}{211} = 3.678$ tonne

طن بالتكيف

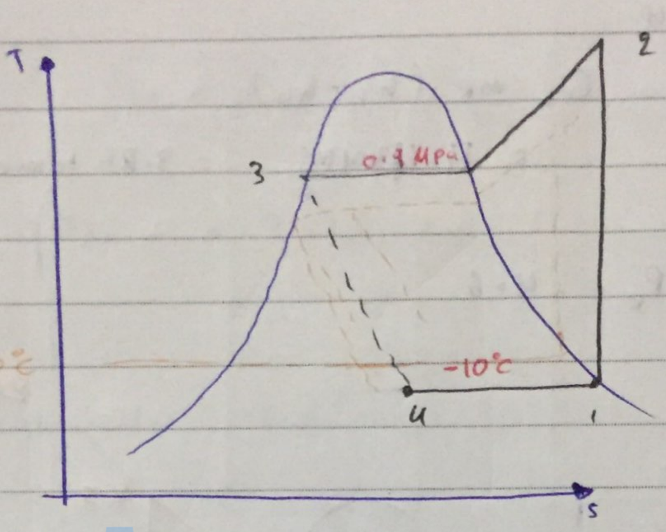
$COP_{max} = \frac{T_L}{T_H - T_L}$

$= 10.075$

$COP_R = \frac{\dot{Q}_L}{\dot{W}_c} = 9.24$

$\eta_{II} = \frac{9.24}{10.075} = 91.7\%$

## Q2



$X_4 = 0.4$

① sat. vapor at $-10°c$

from tables $h_1 = h_f = 244.55$

$s_1 = s_f = 0.93782$

② $0.9$ Mpa. , $S_2 = S_1 = 0.93782$

$h_2 = 275.78$

$\dot{W}_c = \dot{m}_R ( h_2 - h_1 ) = 2.5$ KW ↑

③ sat. Liquid @ 0.9 Mpa $\Rightarrow$ $h_3 = h_f = 101.62$

$S_3 = S_f = 0.37383$

④ $h_4 = h_3 = 101.62$

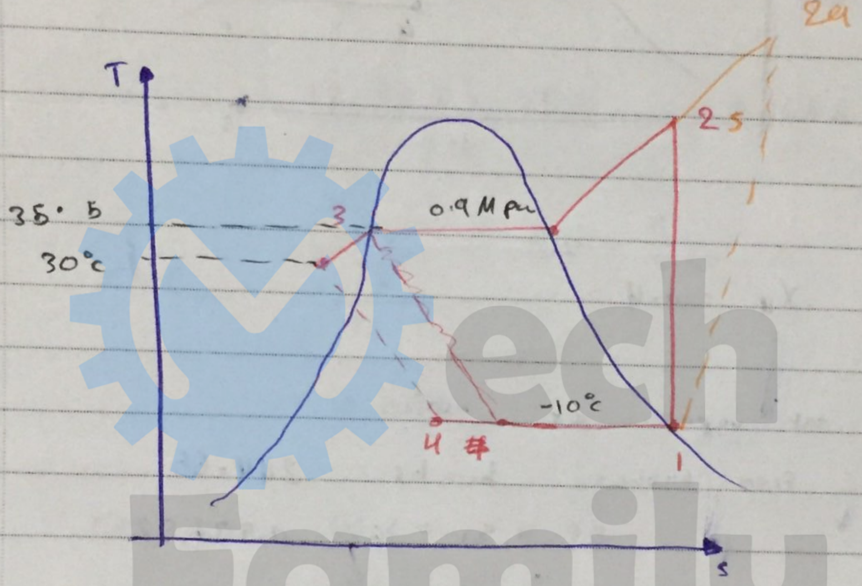
$X_4 = 0.4$

$\dot{Q}_L = \dot{m}_R (h_1 - h_4)$

$= 11.4344 \frac{kJ}{s} = 3.25$ tonne

$COP_R = 4.6$

$\boxed{Q.3}$



$\eta_{sc} = 80\%$

① sat. vapor @ -10°c ⇒ $h_1 = h_g = 244.55$

$s_1 = s_g = 0.93782$

(2s) $h_{2s} = 275.78$

$s_{2s} = s_1 = 0.93782$

(2a) $h_{2a} = ??$ $\eta_{cs} = \frac{h_{2s} - h_1}{h_{2a} - h_1} = 0.8$

$\boxed{h_{2a} = 283.587}$

No.

$s_{2a}$ عند الضغط & $h_{2a}$

$s_{2a} = 0.9623.$

③ sub coold. because $T_3 < T_{sat}$ @ 0.9 Mpa.

$h_3 = h_f = 93.58$

$s_3 = s_f = 0.34792$

④ $h_4 = h_3 = 93.58$

$X_4 = 0.267$ , $S_4 = 0.364114$

$\dot{W}_c = \dot{m}_R (h_{2a} - h_1) = 3.123$ KW

$\dot{Q}_L = 12.07 \frac{KJ}{s} = 3.43$ tonne.

$COP_R = 3.86$

$\dot{X}_{\substack{dest \\ comp \\ 1-2a}} = \dot{m}_R T_o (s_{2a} - s_1) = 0.58$ KW

كان الأصل $\dot{W}_c$ بيستهلك $\boxed{3.123 - 0.58}$

181

No.

$$\dot{X}_{\substack{dest \\ 3-4}} = \dot{m}_R \, T_o \, ( s_3 - s_4 )$$

$$= 0.4 \ Kw.$$

No.

$\boxed{13.10}$

= 12

$Y_i = ??$

$\left.\begin{array}{l} 75\% \ CH_4 \\ 25\% \ CO_2 \end{array}\right\}$ by mass $m_{fi}$

$R_{mix} = ??$

Assume

$m_{mix} = 100$ Kg.

| component | $m_i$ | $M_i$ | $N_i$ | $Y_i$ |
|---|---|---|---|---|
| $CH_4$ | 75 | 16 | 75/16<br>= 4.688 | 0.892 |
| $CO_2$ | 25 | 44 | 0.568 | 0.108 |
|  | 100 |  | 5.286 | 1 |

$M_i$ = from table A-1

$$M_{mix} = \sum Y_i M_i = \frac{m_{mix}}{N_{mix}} = 19.03 \ \frac{Kg}{Kmol}$$

$$R_{mix} = \frac{R_u}{M_{mix}} = 0.437 \ \frac{KJ}{Kg.K}$$

No.

13-11

| component. | $N_i$ | $M_i$ | $m_i$ | $m_{f_i}$ |
|---|---|---|---|---|
| $H_2$ | 5 | 2 | 16 | $\frac{10}{122} = 0.082$ |
| $N_2$ | 4 | 28 | 112 | $\frac{112}{122} = 0.918$ |
| | 9 Kmol | | 122 | |

$$M_{mix} = \frac{122}{9} = 13.56 \ \frac{Kg}{Kmol.}$$

$$R_{mix} = \frac{R_u}{M_{mix}} = \frac{8.314}{13.56} = 0.613$$

No.

**B.28**

30 % $H_2$
40 % He
30 % $N_2$
} by volume ($Y_i$)

Assume $N_{mix} = 1$ Kmol.

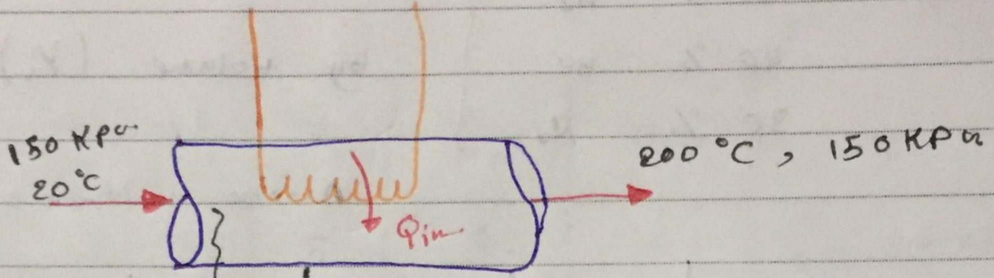
| components | $N_i$ | $M_i$ | $m_i$ | $m_{f_i}$ |
|---|---|---|---|---|
| $H_2$ | 0.3 | 2 | 0.6 | 0.0566 |
| He | 0.4 | 4 | 1.6 | 0.1509 |
| $N_2$ | 0.3 | 28 | 8.4 | 0.7924 |
| | | | Σ 10.6 | |

~~$M_m$~~

$$M_{mix} = \frac{m_{mix}}{N_{mix}} = 10.6 \text{ Kg / Kmol}$$

$$R_{mix} = \frac{R_u}{M_{mix}} = \frac{8.314}{10.6} = 0.7843 \ \frac{KJ}{Kg \cdot K}.$$

$\boxed{13.50}$



30% $O_2$ / 20% $CH_4$ / 40% $N_2$ / 10% $CO_2$

by volume.

$$(Q_{in} - Q_{out}) + (W_{in} - W_{out}) = H_f - H_i$$

$$(q_{in} - q_{out}) + (w_{in} - w_{out}) = h_f - h_i$$
$$= c_p\,(T_2 - T_1)$$

$$q_{in} = c_{p_{mix}}\,(T_2 - T_i)$$

$$c_{p_{mix}} = \sum m_{fi}\ c_{pi}$$

Assume

$N_{mix}$ = 100 Kmol

| component | $N_i$ | $M_i$ | $m_i$ | $m_{fi}$ | $c_{pi}$ |
|---|---|---|---|---|---|
| $O_2$ | 30 | 32 | | 0.338 | 0.918 |
| $CO_2$ | 10 | 44 | | 0.155 | 0.8469 |
| $N_2$ | 40 | 28 | | 0.3943 | 1.039 |
| $CH_4$ | 20 | 16 | | 0.1126. | 2.2537 |

$$\sum m_{fi}\ c_{pi} = c_{p_{mix}} = 1.1051\ \frac{KJ}{Kg.K}$$

$\boxed{1.86}$

No.

|  | $m_{fi}$ | $c_{pi}$ |
|---|---|---|
| $O_2$ | 0.3103 |  |
| $CO_2$ | 0.1315 |  |
| $N_2$ | 0.4696 |  |
| $CH_4$ | 0.2539. |  |

$$c_{p\,mix} = 1.1051 \ \frac{KJ}{Kg.K}$$

$$\therefore \quad q_{in} = 1.6051 * (200 - 20)$$

$$\text{or} \quad m_{fi} = \frac{y_i \quad M_i}{M_{mix}}$$

No.

* win *

$\boxed{13.52}$

$$\left.\begin{array}{l} 30\ \%\ H_2 \\ 40\ \%\ He \\ 30\ \%\ N_2 \end{array}\right\}\ \text{by Volume.}$$

Expansion , isentropic

Initial 5 Mpa , 600°C

final 200 Kpa

Sol'n

closed system.

$$(\cancelto{0}{q_{in}} - \cancelto{0}{q_{out}}) + (w_{in} - w_{out}) = u_f - u_i$$

$$W_{Exp} = u_1 - u_2$$

$$= c_{v_{mix}} (T_1 - T_2)$$

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{K_{mix} - 1}{K_{mix}}}$$

$$K_{mix} = \frac{Cp_{mix}}{Cv_{mix}}$$

$$R_{mix} = Cp_{mix} - Cv_{mix}$$

No.

$Cp_{mix} = 2.4166$

$R_{mix} = 0.7843$

$Cv_{mix} = 1.633$

$K_{mix} = 1.48$

$T_{final} = 307 \ K$

$W_{exp} = 924.28 \ \frac{KJ}{Kg}$

No.

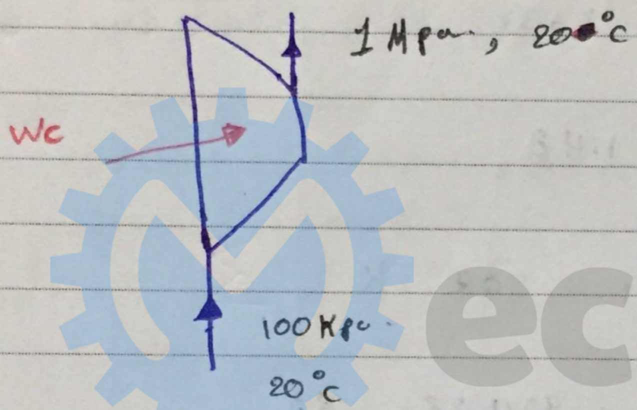
13-56

60 % $CH_4$

25 % $C_3H_8$

15 % $C_4H_{10}$

by weight = $m_{fi}$



$$W_{in} = q_{out} = R_{mix} \; T_{mix} \; Ln\left(\frac{P_2}{P_1}\right)$$

$M_{mix} = 21.85$ Kg / Kmol.

$R_{mix} = 0.3805$

$\therefore W_{in} = 257 \frac{KJ}{Kg} = q_{out}.$

## ** $P - \forall - T$ behavior of Gas Mixture. *

### 1 Dalton's law of partial pressure.

$$\overset{A}{\boxed{\begin{matrix}\forall, T \\ P_A\end{matrix}}} + \overset{B}{\boxed{\begin{matrix}\forall, T \\ P_B\end{matrix}}} + \overset{C}{\boxed{\begin{matrix}\forall, T \\ P_C\end{matrix}}} = \boxed{\begin{matrix}\forall_{mix}, T_{mix} \\ P_{mix}\end{matrix}}$$

$$P_{mix} = P_A + P_B + P_C$$

→ For the same $[\forall, T]$

$$P_{mix}\forall_{mix} = m_{mix} R_{mix} T_{mix} = \overbrace{N_{mix}\,M_{mix}}^{m_{mix}}\kern-2.2em\underbrace{\phantom{M_{mix}}\,R_{mix}}_{Ru}\,T_{mix}$$

$$\boxed{R_{mix} = \frac{Ru}{M_{mix}}} \quad \boxed{P_{mix}\forall_{mix} = N_{mix}\, Ru\, T_{mix}}$$

$$P_A * \forall_A = N_A\, Ru\, T_{mix}.$$

$$P = F(N)$$

No.

$$\frac{P_A}{P_{mix}} = \frac{\frac{N_A \cancel{R_u} \cancel{T_{mix}}}{\cancel{\forall_{mix}}}}{\frac{N_{mix} \cancel{R_u} \cancel{T_{mix}}}{\cancel{\forall_{mix}}}} = \frac{N_A}{N_{mix}} = y_A$$

→ component pressure ( partial pressure )

For Dalton's

$$P_{mix} = \sum_{i=1}^{K} P_i(\forall, T)$$

$$\overset{A}{\boxed{\begin{matrix} \forall, T \\ P_A, N_A \end{matrix}}} + \overset{B}{\boxed{\begin{matrix} \forall, T \\ P_B, N_B \end{matrix}}} + \overset{C}{\boxed{\begin{matrix} \forall, T \\ P_C, N_C \end{matrix}}} = \boxed{\begin{matrix} \forall_{mix}, T_{mix} \\ P_{mix} \end{matrix}}$$

## Amagats law of partial ∀olume.

$$\underset{A}{\boxed{\begin{matrix} P, T \\ \forall_A \end{matrix}}} + \underset{B}{\boxed{\begin{matrix} P, T \\ \forall_B \end{matrix}}} + \underset{C}{\boxed{\begin{matrix} P, T \\ \forall_C \end{matrix}}} = \boxed{\begin{matrix} (P, T)_{mix} \\ \forall_{mix} \end{matrix}}$$

$$\therefore \quad \forall_{mix} = \forall_A + \forall_B + \forall_C$$

$$\forall_{mix} = \frac{N_{mix} \; R_u \; T_{mix}}{P_{mix}}$$

$$\frac{\forall_A}{\forall_{mix}} = \frac{N_A}{N_{mix}} = Y_A$$

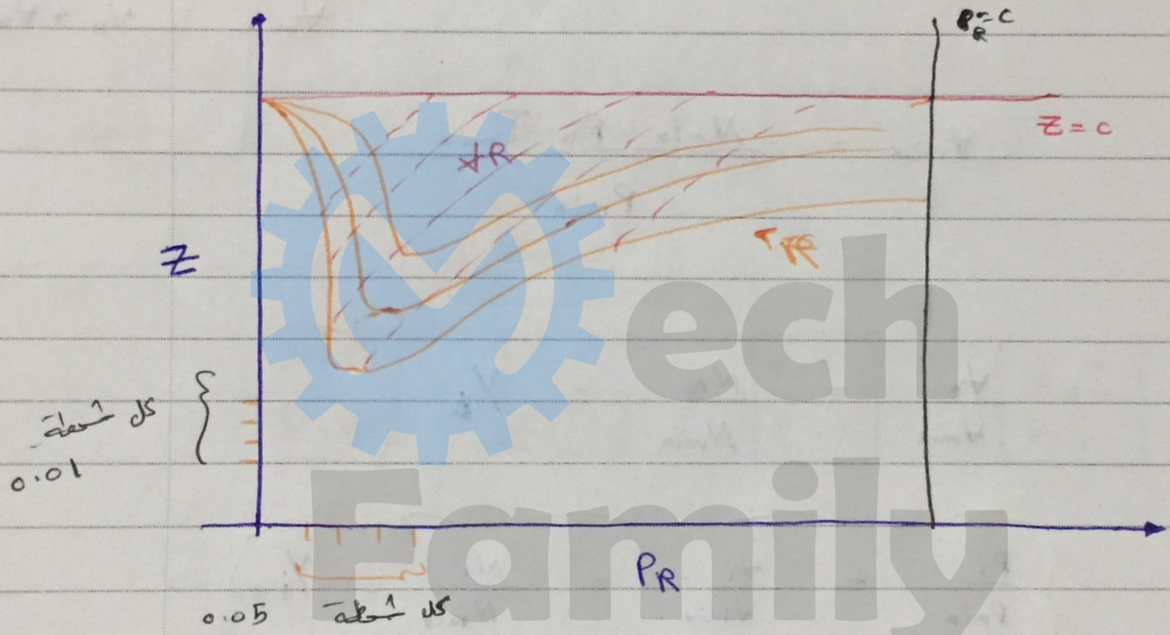
$$\boxed{\frac{P_i}{P_{mix}} = \frac{\forall_i}{\forall_{mix}} = \frac{N_i}{N_{mix}} = Y_i}$$

only for ideal gas

## General

$$P \forall = Z N R_u \; T$$

For ideal gas. $Z = 1$ <
- low P
- $T > T_{cr}$



$$P_R = \frac{P}{P_{cr}}$$ ⇝ from table A-1

No.

→ How to find $Z_{mix}$ ??

* Amagats Rule.

$$Z_{mix} = \sum Y_i Z_i$$

$\boxed{I}$ Find $Y_i$

$\boxed{II}$ Find $(P_R, T_R)_i$ then from chart $Z_i$

* Kay Rule

$\boxed{I}$ Find $Y_i$

$\boxed{II}$ Find pseudo $(P'_{CR}, T'_{CR})$

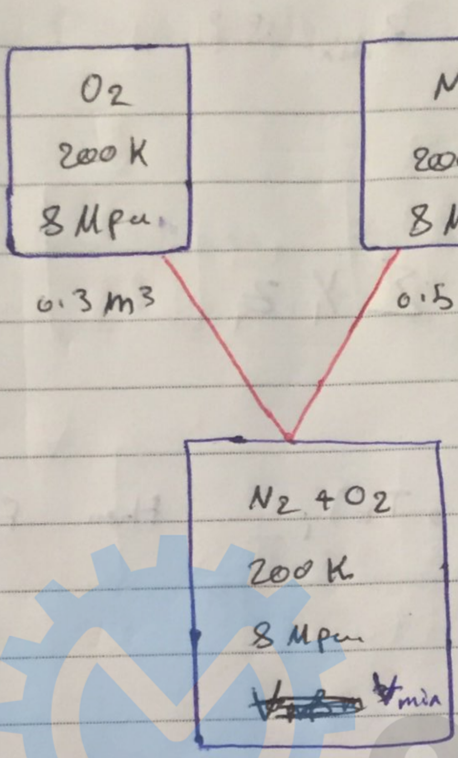
$$T'_{CR} = \sum Y_i T_{CR_i}$$

$$P'_{CR} = \sum Y_i P_{CR_i}$$

$\boxed{III}$

$$\left.\begin{aligned} T_{R_{mix}} &= \frac{T_{mix}}{T'_{CR}} \\ P_{R_{mix}} &= \frac{P_{mix}}{P'_{CR}} \end{aligned}\right\} Z_{mix}.$$

Q $\boxed{13.37}$



$\boxed{1}$ ~~Ideal g~~

$\boxed{1}$ Ideal Gas using Amagats Law

$$\forall_{mix} = \sum \forall_i = 0.8\ m^3$$

$\boxed{3}$ ① using Ideal Gas

since $(T_i , P_i) = (T_{mix} , P_{mix})$

∴ using Amagats law

$$\forall_{mix} = \sum \forall_i \quad (P_m, T_m) = 0.8\ m^3$$

No.

$$V_{mix} = \frac{N_{mix} \quad R_u \quad T_{mix}}{P_{mix.}}$$

Kpa (8000)

$N_{O_2} = 1.443$ , $N_{N_2} = 2.406$

$N_{mix} = 3.849$ Kmol

→ Non Ideal Gas :

Ⓘ Amagats Rule.

step 1 : Find $Y_i$

$$Y_{O_2} = \frac{1.443}{3.849} = 0.375$$

$$Y_{N_2} = \frac{2.406}{3.849} = 0.625$$

step 2 : Find $T_{CR}$ , $P_{CR}$ for each gas.

from Table A-1 , for $O_2$

$P_{CR} = 5.08$ Mpa

$T_{CR} = 154.8$ K

for $N_2$ $P_{CR} = 3.39$ Mpa , $T_{CR} = 126.2$ K

For $O_2$

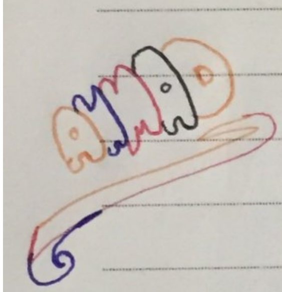
$$T_{R_{O_2}} = \frac{200}{154.8} = 1.3$$

$$P_{r_{O_2}} = \frac{8}{5.08} = 1.575 \simeq 1.6$$

From chart

$Z_{O_2} = 0.76$

$\simeq 0.77$ —



For $N_2$

$$T_{R_{N_2}} = \frac{200}{126.2} = 1.6$$

$$P_{R_{N_2}} = \frac{8}{3.39} = 2.36$$

From chart

$Z_{N_2} = 0.87$

$\simeq 0.86$ —

Step 3 : Find $Z_{mix}$

$$Z_{mix} = \sum Y_i Z_i$$

$$= 0.826.$$

$$P\cancel{_{mix}}\ V_{mix} = Z_{mix} N_{mix} R_u T_{mix}.$$

$$\therefore V_{mix} = 0.661 \text{ m}^3$$

No.

## (II) Kay Rule:

step(1) : Find $y_i$

$y_{O_2} = 0.375$

$y_{N_2} = 0.625$

step (2) : Find $T_{cR}$ , $P_{cR}$ , for each

from table A-1, for $O_2$

$P_{cR} = 5.08$ Mpa

$T_{cR} = 154.8$ K

for N2

$P_{cR} = 3.39$ Mpa

$T_{cR} = 126.2$ K.

step (3) : Find ~~Find~~ $T'_{cR_{mix}}$ , $P'_{cR_{mix}}$

$$T'_{cR_{mix}} = \sum y_i \, T_{cR_i} = 137.7 \text{ K}$$

$$P'_{cR_{mix}} = \sum y_i \, P_{cR_i} = 4.07 \text{ Mpa}$$

$\boxed{200}$

$PV = mRT$
$= N \bar{R}_u T$

No.

Step (4): Find $T_{R_{mix}}$ , $P_{R_{mix}}$

$$T_{R_{mix}} = \frac{T_{mix}}{T'_{CR_{mix}}} = 1.45$$

$$P_{R_{mix}} = \frac{P_{mix}}{P'_{CR}} = 1.96 \simeq 1.95$$

from chart

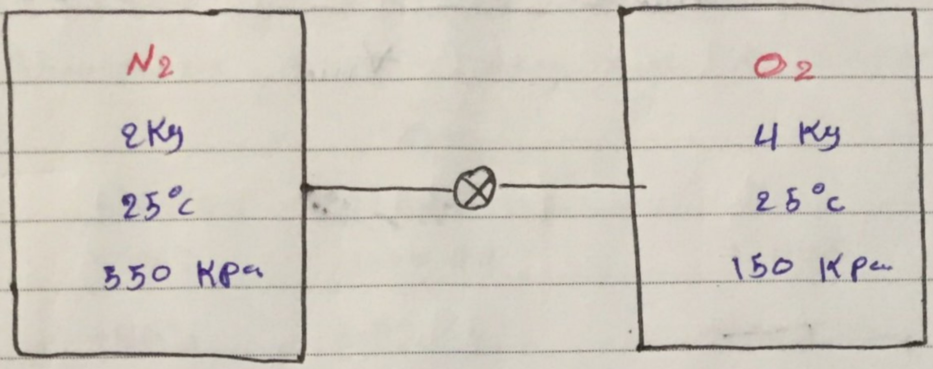
$Z_{mix} = 0.82$

$V_{mix} = 0.652.$

No.

$\boxed{Q13.32}$ ≡ 32

$R_{N_2} = 0.2968 \ \frac{kJ}{kg.K}$ $R_{O_2} = 0.2598 \ \frac{kJ}{kg.K}$



$\boxed{sol}$ (I) **Befor mixing** $N_{O_2}$ , $N_{N_2}$

$\forall_{O_2}$ , $\forall_{N_2}$

$N_{O_2} = \frac{2*2}{32} = 0.125$ Kmol

$N_{N_2} = \frac{2}{28} = 0.07143$ Kmol

$\forall_{O_2} = \frac{m_{O_2} R_{O_2} T_{O_2}}{P_{O_2}} = 2.0645 \ m^3$

$= \frac{N_{O_2} \ R_u \ T_{O_2}}{P_{O_2}} = 2.0645 m^3$

$\forall_{N_2} = 0.3216 \ m^3$

(II) **After mixing** :- $P_{mix}$ is uniform

$\forall_{mix} = \forall_{O_2} + \forall_{N_2}$

$= 2.3861 \ m^3$

$\boxed{2021}$

No.

$$P_{mix} = \frac{N_{mix}\ R_u\ T_{mix}}{V_{mix}} = 203.96\ \text{Kpa}$$

## CH#14: Gas - vapor mixture.

Atmospheric Air = dry air + vapor.

| | $C_{p\,air}$ |
|---|---|
| -10 °C | 1.0038 |
| 20°C | 1.0049 |
| +50°C | 1.0665 |

1.005

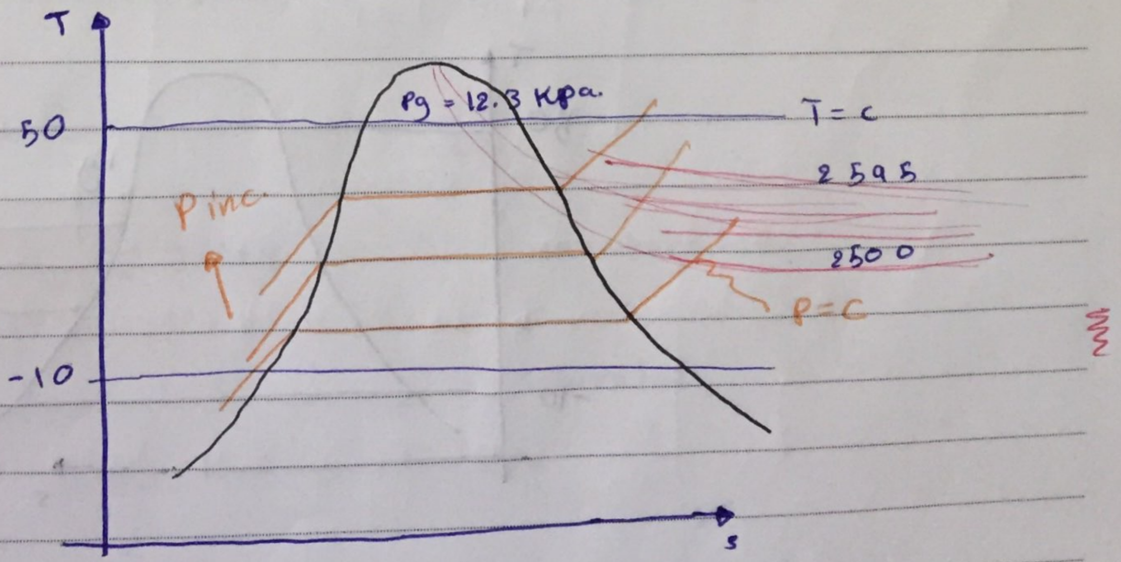
error ± 0.2%

$$h_{dry\ air} = C_p\ T$$

$$= 1.005 * T^{°C}$$

$$\Delta h = C_p\ \Delta T$$

ال vapor behaves as an ideal gas لكن هو مش gas.



2014

No.

$P_{atm} = P_a + P_v$

dry air $h_a = c_p T = 1.005 * T$ T (°C)

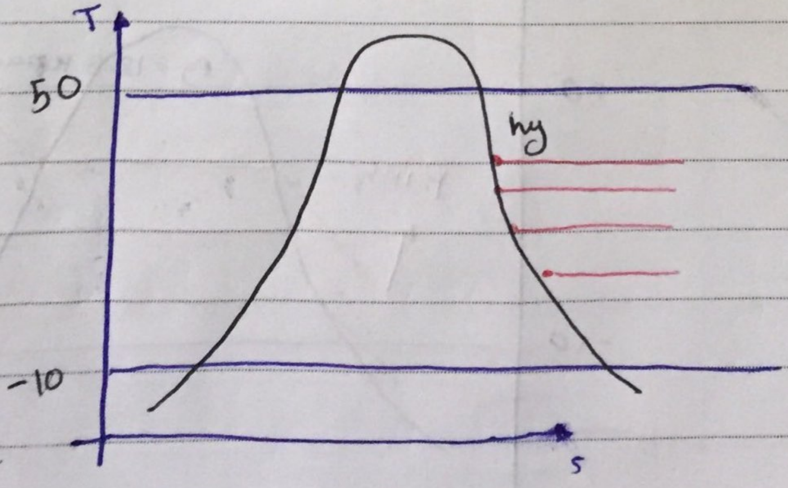
$\Delta h_a = c_p \Delta T = 1.005 * \Delta T$

vapor $h_v (T, low P) = h_g (T)$ (°C)

$= 2500.9 + 1.82 T$

$P = P_a + P_v$

*** For total dry air $P_v = 0$



$\boxed{205}$

No.

→ How to define the vapor quantity in air ?

$\boxed{1}$ specific / Absolute Humidity "ω" $= \frac{m_v}{m_a}$

$= \cancel{P_v \forall}$

الرطوبة النوعية

$$\omega = \frac{\frac{P_v \cancel{\forall}}{R_v \cancel{T}}}{\frac{P_a \cancel{\forall}}{R_a \cancel{T}}} = 0.622 \, \frac{P_v}{P_a}$$

$$= 0.622 \, \frac{P_v}{P - P_v}$$

$P_v = 0$, $m_v = 0$, dry air

$\omega = 0$

$P_v = P_g \text{ sat} = P_{sat} @ T$

Ex: 100 Kpa , 25°C → $P_g = 3.169$ Kpa

$P_v = 0$ dry air.

$P_v < 3.169$ unsaturated.

$P_v = 3.169$ saturated.

No.

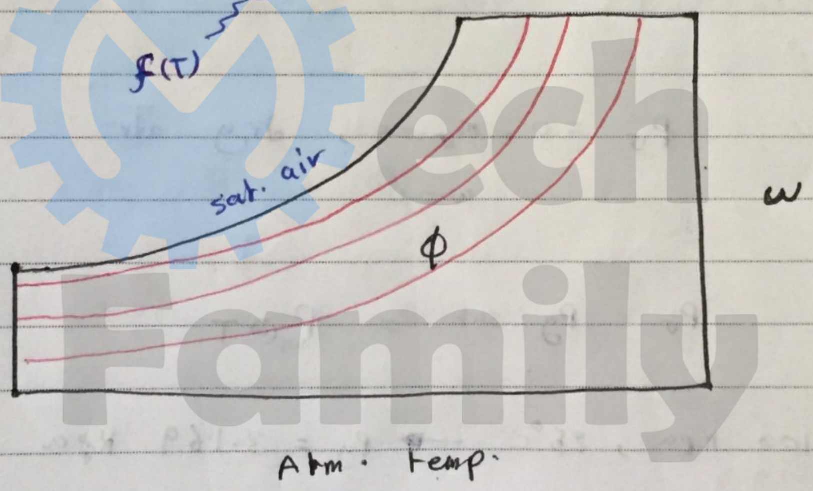
$\boxed{2}$ Relative Humidity $\phi = \frac{m_v}{m_g}$

$= \frac{P_v}{P_g}$ (0 → 1)

$\omega = \frac{m_v}{m_a} = 0.622 \frac{P_v}{P_a}$ ~ عند تبريد أو تسخين الهواء تبقى ثابتة

$\phi = \frac{m_v}{m_g} = \frac{P_v}{P_g}$ ↑ ~ عند تبريد الهواء

f(T)



30°c , $\phi = 80\%$.

At 30°c ⟶ $P_g = 4.2469$ kPa (From steam tables)

$\phi = \frac{P_v}{P_g} \Rightarrow P_v = 3.4$ kPa.

$P_{atm} = P_a + P_v \Rightarrow P_a = 96.4$ kPa

$\boxed{207}$

No.

$\phi = 1$ @ $P_v = P_g = 3.4$ Kpa

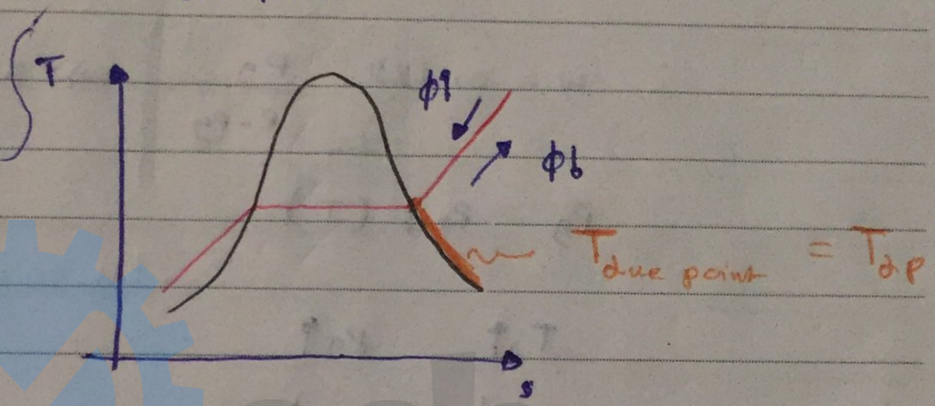
$\Downarrow$

$T = 26°c$

due point

$30°c \rightarrow 25°c$

$m_L = mv_{30} - mv_{25}$



كل ما زادت $\phi$ للجو كل ما زادت درجة حرارة ال dp

At $30°c$, $\phi = 50\%$

At $30°c \rightarrow P_g = 4.2469$ Kpa (from steam tabl

$\phi = \frac{P_v}{P_g} \rightsquigarrow P_v = 2.12345$

$$\phi = \frac{wP}{(0.622 + w)\,P_g} = \frac{0.622\,\phi\,P_g}{P - \phi\,P_g}$$

No.

$P = P_v + P_a$

① $w = \frac{m_v}{m_a} = 0.622 \frac{P_v}{P_a} = 0.622 \frac{P_v}{P - P_v}$

$w = 0.622 \frac{P_g}{P - P_g}$ sat air.

$P_g = P_{sat}(T)$

$T \uparrow \quad P_g \uparrow$

$\downarrow \quad \downarrow$

$P_v < P_g$ un sat air

$= P_g$ sat. air.

② $\phi = \frac{m_v}{m_g} = \frac{P_v}{P_g}$ $0 \rightarrow 1$

simple heating /cooling

$\left.\begin{matrix} m_v \\ m_a \\ P_v \\ P_a \end{matrix}\right\} \longrightarrow$ const.

$w \rightarrow$ const

$P_g$ varies.

$\phi$ varies.

$$\frac{H}{m_a} = \frac{H_a}{m_a} + \frac{H_v}{m_a} \quad m_v h_v$$

$\frac{KJ}{kg\ dry\ air}$

$$h = h_a + \omega h_v$$

$$= c_p T + \omega h_v$$

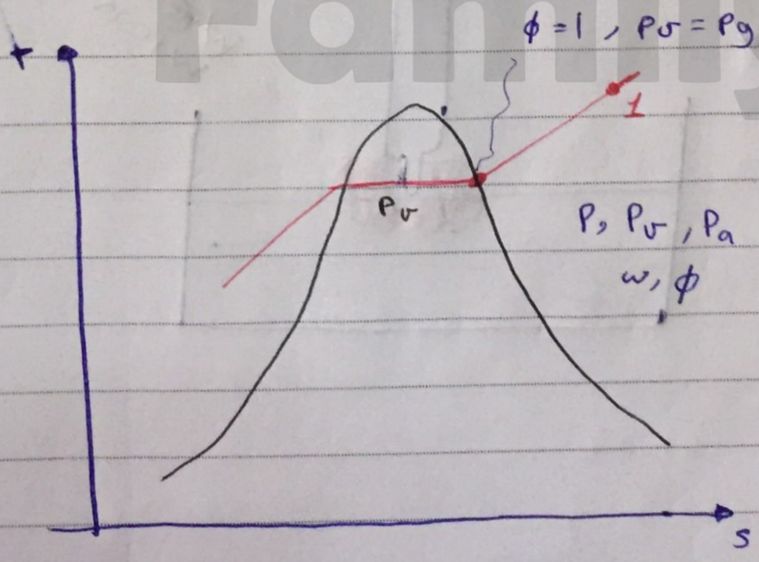
$T_{dp}$ dew point

$T_{db}$ dry bulb

$T_{wb}$ wet bulb.

$T_{dp}$

درجة الحرارة
الي بيبدأ
عندها ال
vapor
يتكثف



$P, P_v, P_a$

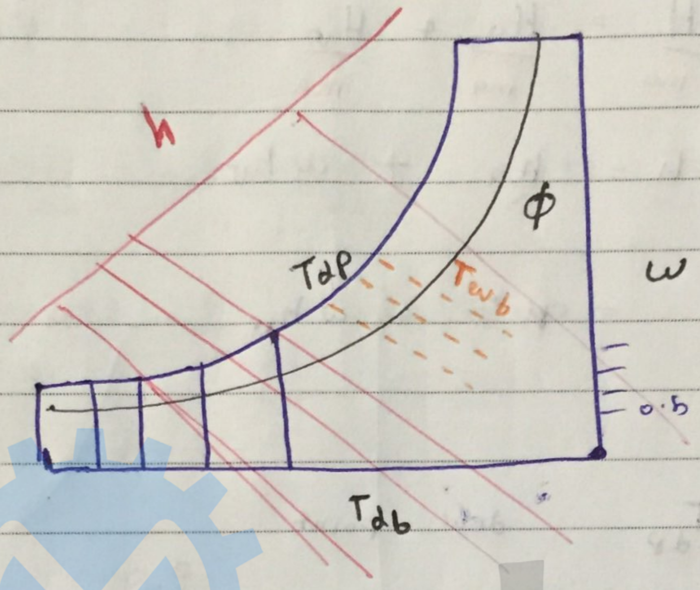
$\omega, \phi$

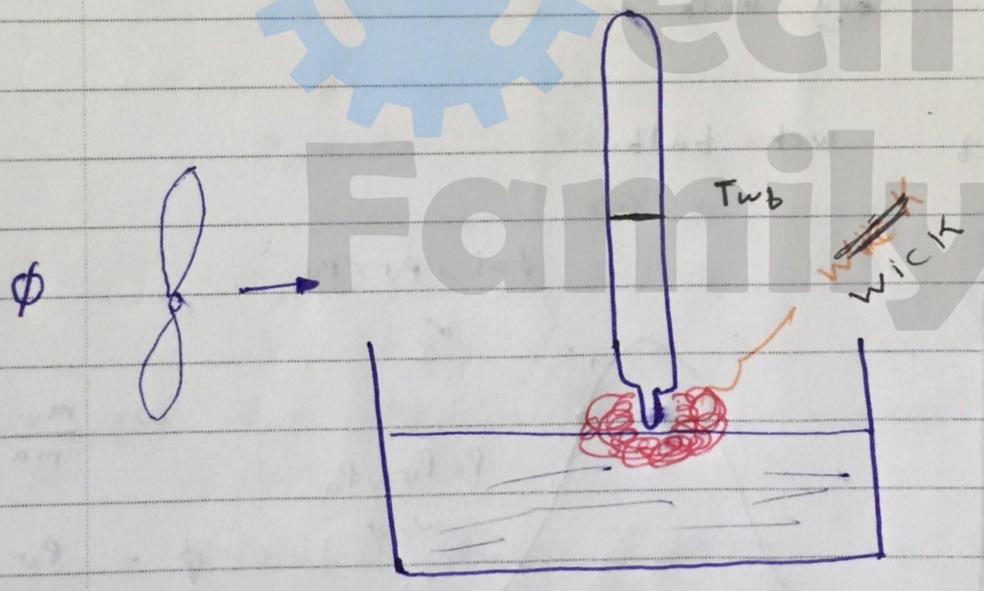
$\omega = \frac{m_v}{m_a}$ = const.

$\phi = \frac{P_v}{P_g} \downarrow$

$T_{db}$ الحرارة العادية الي بنحسها

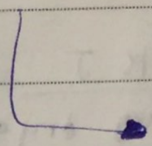
No.





No.

dry bulb 30°C $\phi = 80\%$



$\Downarrow$

$\omega = 21.5$

$T_{db} = 30°C$

$T_{dp} = 26°C$

@ $\phi_1 \Rightarrow T_{dp} = T_{db}$

dry bulb 30°C $\phi = 50\%$

$\Downarrow$

$T_{dp} = 19$

@ dry bulb 40°C $\phi = 50\%$

$\phi = 90\%$

No.

$\boxed{1}$ $\underbrace{\phi = 50\% \quad , w = 0.01}$

$h = 50.75 \frac{KJ}{Kg\ dry\ air}$

$T_{dp} = 14°c$

$T_{db} = 25.12°c$

$\upsilon = 0.858 \frac{m3}{Kg\ dry\ air}$

$T_{wb} = 18°c$

$\boxed{2}$ $T_{db} = 25°c$

$\phi = 80\%$

$h = 66 \frac{KJ}{Kg\ dryair}$

$T_{dp} = 21.3°c$

$w = 0.016$ Kg

$T_{wb} = 22.4°c$

$\upsilon = 0.866$

No.

3| $T_{dp} = 20°C$ , $T_{db} = 20°C$ } $\phi = 100\ \%$

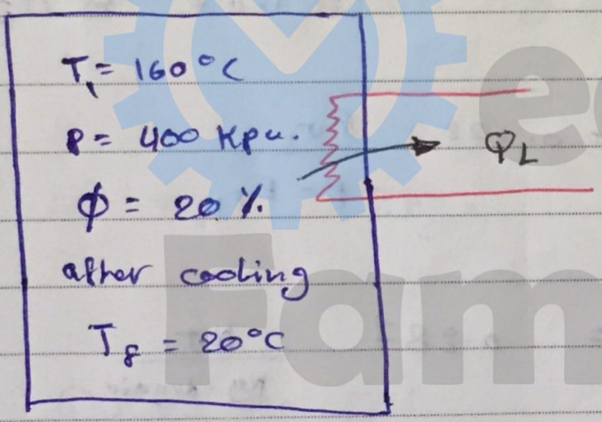
$\omega = 0.0147$

$h = 58 \cong$ ~~8~~ $57.6$

$\upsilon = 0.85$

$T_{wb} = 20°C$

① Rigid tank $2m^3$,



Find $Q_L = ??$ , $T_{dp} = ??$

وهل راح يكون في تكثف او لأ .

step 1 Find $P_{g_1}$ from tables @ $T_1 = 160°C$ ,

$\rightarrow P_{g_1} = 617.8$ KPa

$\therefore \phi = \frac{P_{v_1}}{P_g} \Rightarrow P_{v_1} = 0.2 * 617.8$

$= 123.6$ Kpa

$T_{dp} = T_{sat}(P_v) = 107°c$

∴ since $T_2 < T_{dp} \Rightarrow$ there will be cond

$\dot{m}_f = \dot{m}_a \, (w_1 - w_2)$

from table

$$v_{f_1} = \frac{R_v \, T_1}{\underbrace{P_1}_{P_{v_1}}} = \frac{\overbrace{0.462} * 433}{\cancel{1262} \; 123.6}$$

$$= 1.62 \ m^3/Kg$$

$$w_1 = 0.622 \, \frac{P_{v_1}}{P - P_{v_1}}$$

$$= 0.287 \ \frac{Kv}{Kg \cdot dryair}$$

$P_{a_1} = 400 - 183.6 = 276.4$ Kpa.

step 2 After cooling

$T_2 = 20°c \qquad \phi = 100\%$

$P_{v_2} = P_{g_2}\big|_{20°c} = 2.338$ Kpa

$w_2 = ??$ $\qquad \frac{P_{a_1}}{T_1} = \frac{P_{a_2}}{T_2} \Rightarrow P_{a_2} = 187$ Kp

No.

$$w_2 = 0.622 \frac{P_{v_2}}{P_{a_2}}$$

$$= 0.00778$$

$$m_{a_1} = \frac{P_{a_1} V_1}{R_a T_1}$$

$$= 4.45 \text{ Kg}$$

$$\boxed{w = \frac{m_v}{m_a}}$$

$$\therefore \quad m_f = 1.2 \text{ Kg}$$

$$U = U_a + w\, U_v$$

$$h = h_a + w\, h_v$$

$U_g$ from tables.

$$Q_L = m_a \Delta U$$

$$= m_a \Big[ (u_{a_2} - u_{a_1}) \cancel{m_{v_2}}$$

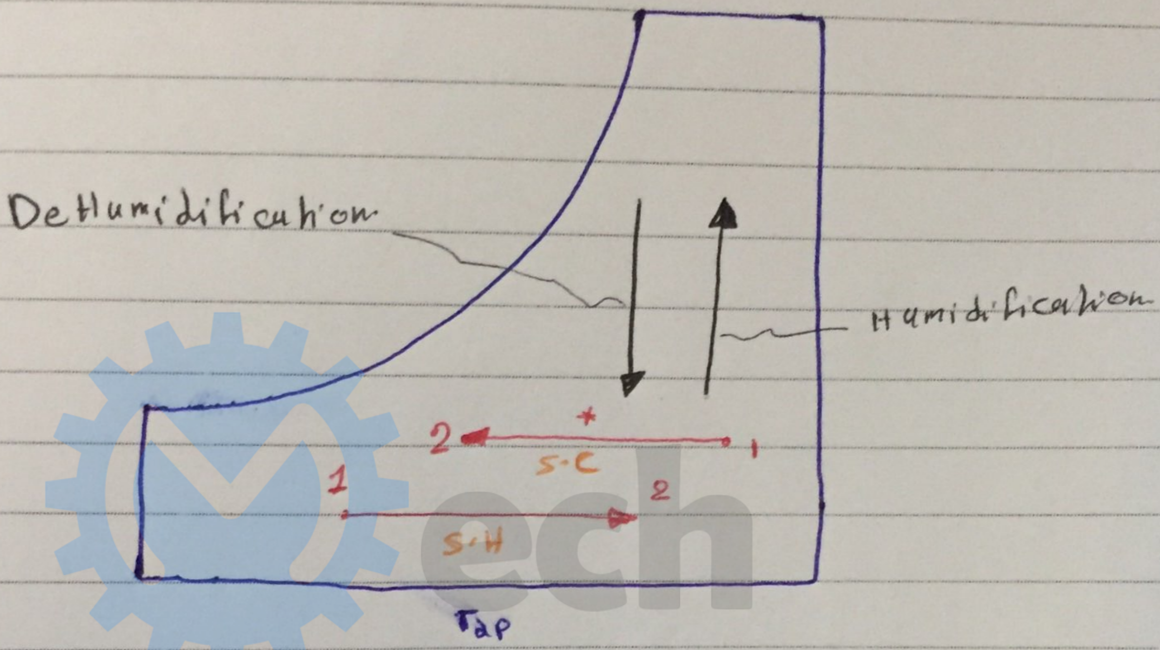
$$+ \Big( \overset{w_2}{\frac{m_{v_2}}{m_a}} U_{v_2} - \overset{w_1}{\frac{m_{v_1}}{m_a}} U_{v_1} \Big) \Big]$$

$$+ m_f h_{fg}.$$

$$= m_a c_v (T_{a_2} - T_{a_1}) +$$

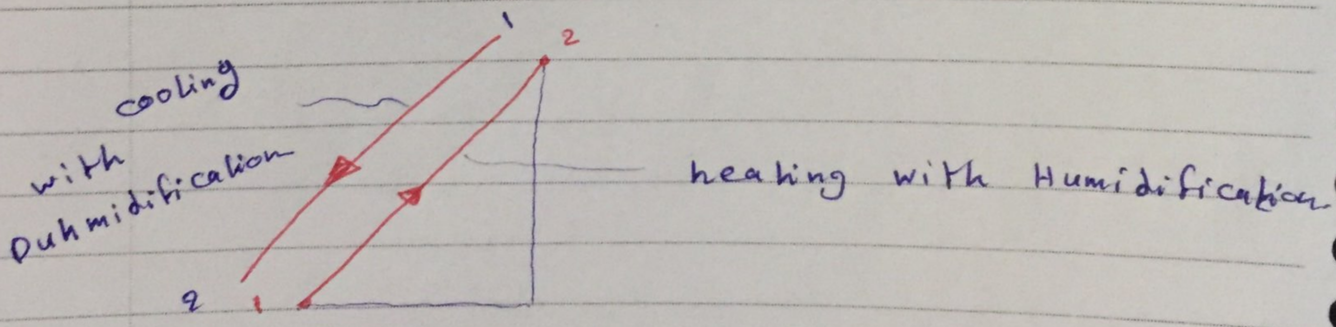
$$= 4.45 \Big[ (0.717 (20 - 160)) + 0.00778 \times 2402.9 - 0.278 \times 2566.4)$$

$$+ 1.2 \times 2365 ) \Big] = -6290 \text{ KJ}$$



1 → 2 1-2 → simple heating.

2 ← 1 1-2 → simple cooling

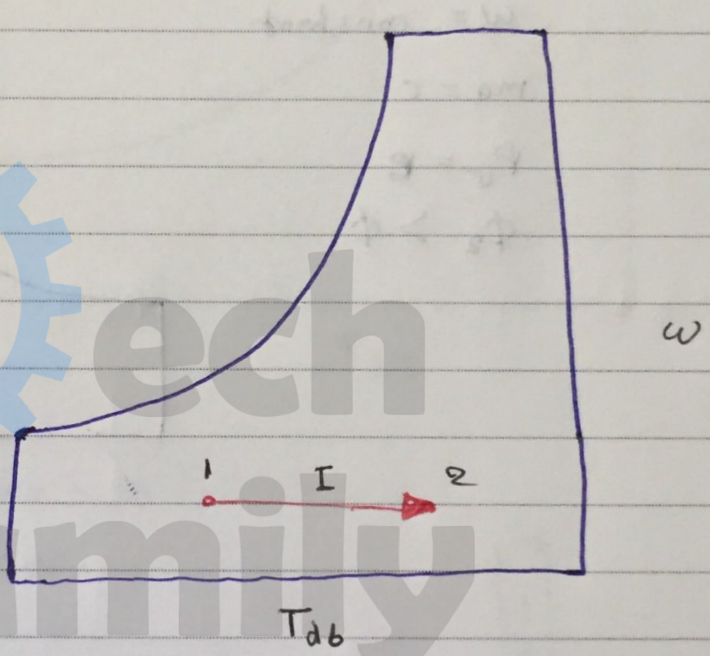


No.

# Air conditioning processes.

## I) simple heating
sensible

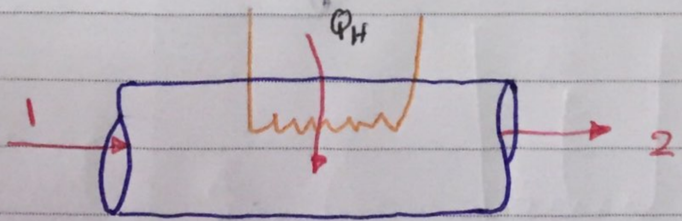
1 -> 2



$\omega_1 = \omega_2$ , $m_a = c$ $\therefore$ $m_{v_1} = m_{v_2}$

$P_{v_1} = P_{v_2}$

$\phi_2 < \phi_1$ since $P_{g_2} > P_{g_1}$



$$\dot{Q}_H = \dot{m}_a (h_2 - h_1)$$

No.

## II) simple cooling

only If

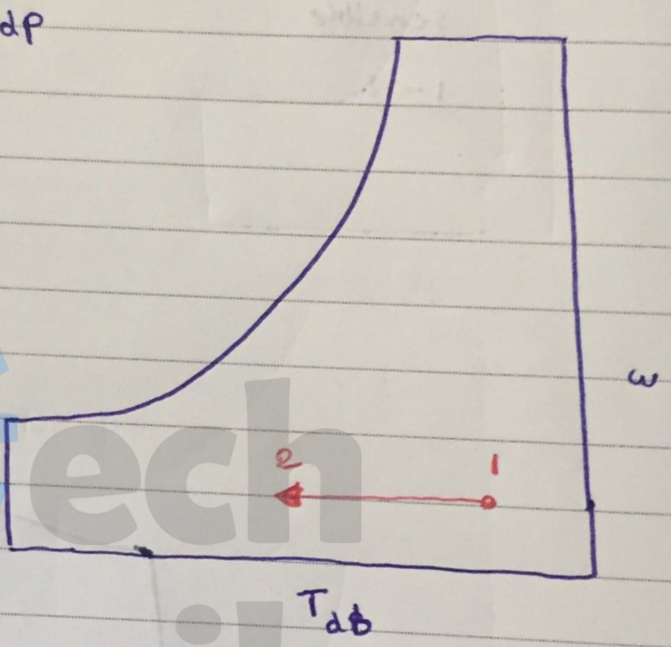
$T_2 \geq T_{dp}$

$\omega =$ constant

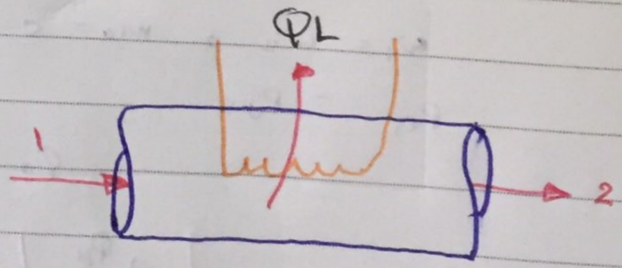
$m_a = c$

$P_v = c$

$\phi_2 > \phi_1$



$\dot{Q}_L = \dot{m}_a (h_1 - h_2)$



## III) Humidification

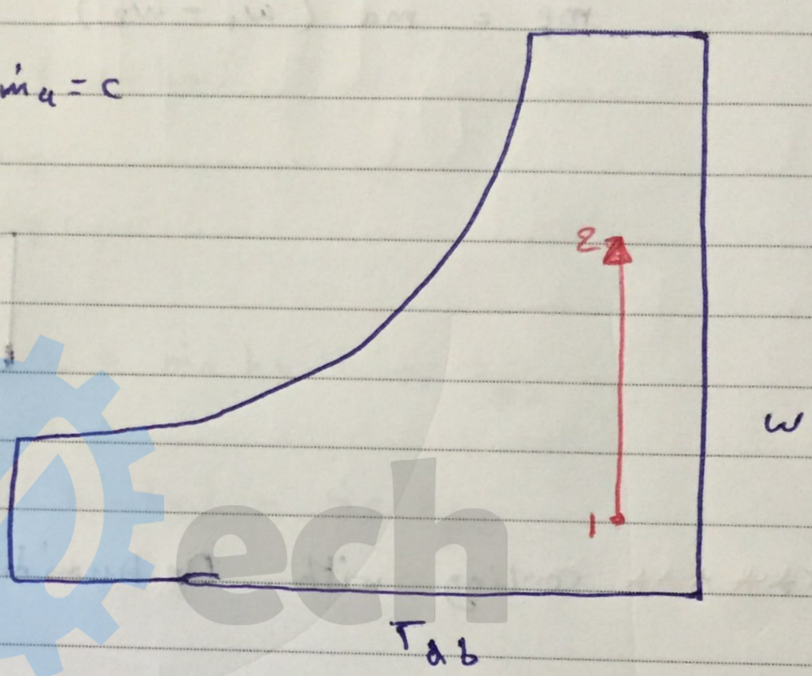
$T_{db} = c$ , $\dot{m}_a = c$

$\omega_2 > \omega_1$

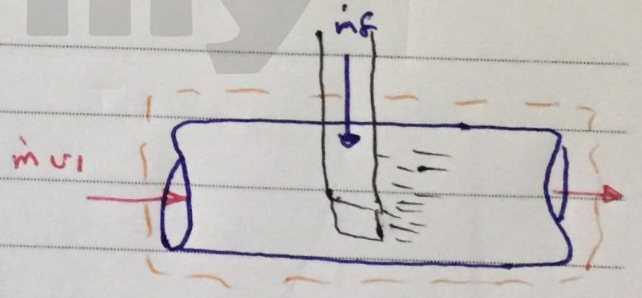
∴ $\dot{m}_{v_2} > \dot{m}_{v_1}$

$P_{v_2} > P_{v_1}$

$\phi_2 > \phi_1$

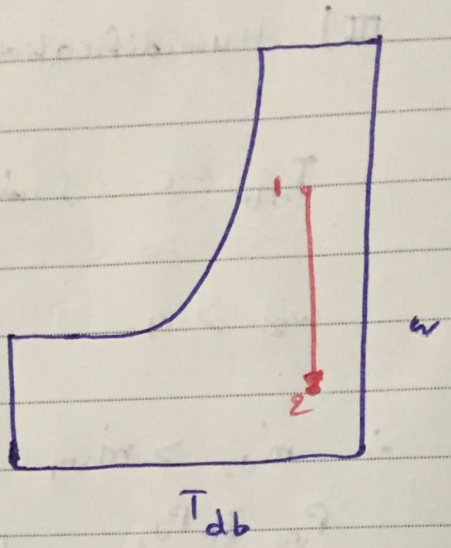


$$\dot{m}_f = \dot{m}_a\,(\omega_2 - \omega_1)$$
$$= \dot{m}_{v_2} - \dot{m}_{v_1}$$

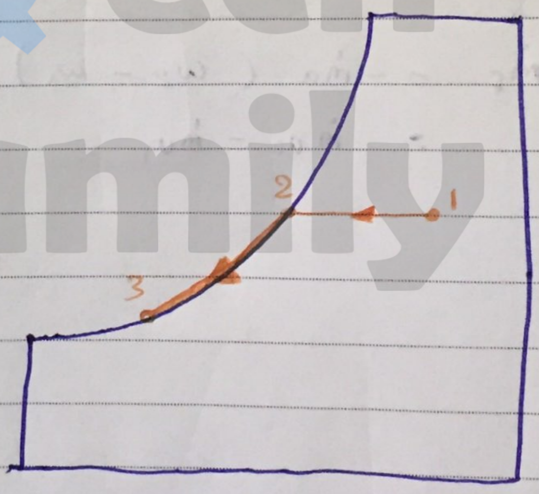


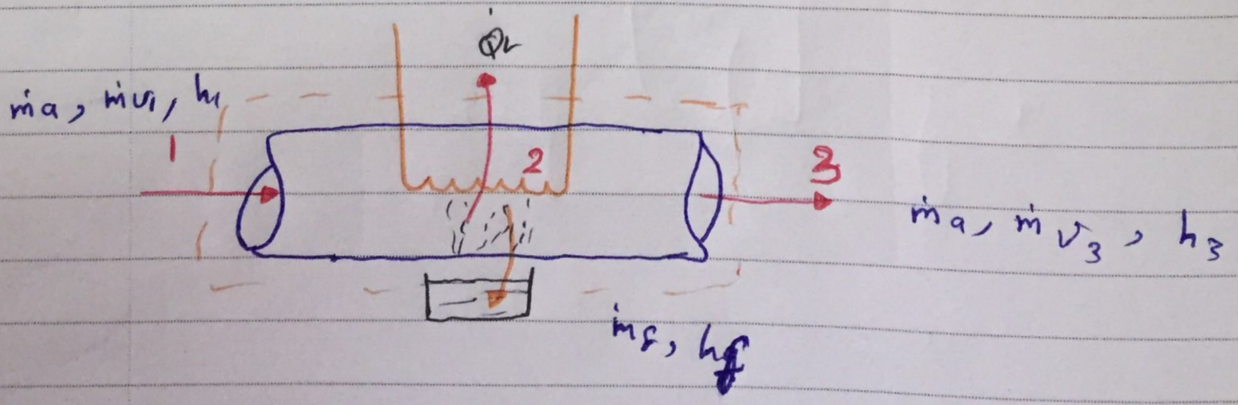
## IV) de-Humidification

$\dot{m}_f = \dot{m}_a ( w_1 - w_2 )$



******* cooling with De humidification





1-2) simple cooling

$$\dot{Q}_L = \dot{m}_a (h_1 - h_2)$$

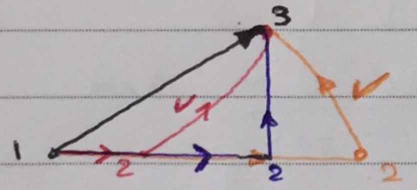
$$\omega_3 < \omega_2$$

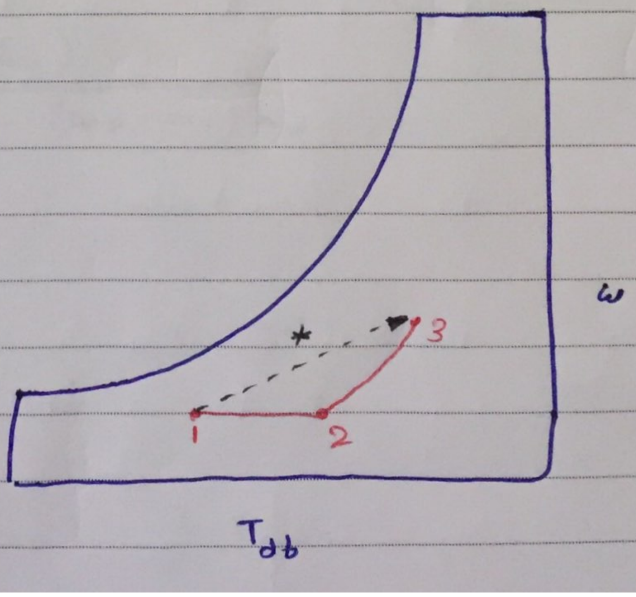
$$\phi_3 = \phi_2$$

$$\dot{m}_a h_1 = \dot{Q}_L + \dot{m}_a h_3 + \dot{m}_f h_{f2}$$

$$\therefore \dot{Q}_L = \dot{m}_a (h_1 - h_3) - \dot{m}_f h_{f2}$$

** ** ** heating with humidification





No.

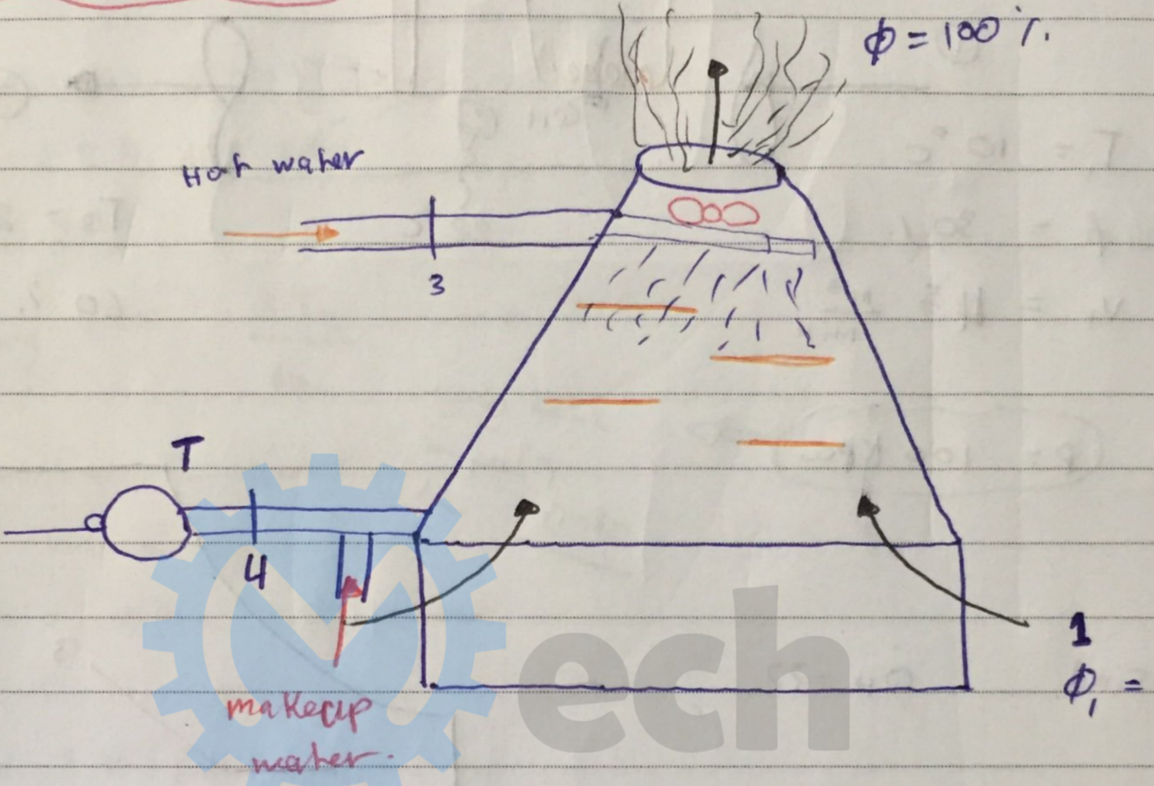
1-2) simple heating

$$\dot{Q}_H = \dot{m}_a (h_2 - h_1)$$

2-3) $\dot{m}_w = \dot{m}_a (w_3 - w_2)$

$$\dot{m}_a (h_1 - h_3) - \dot{m}_f h_f = \dot{m}_R (h_1 - h_4)$$

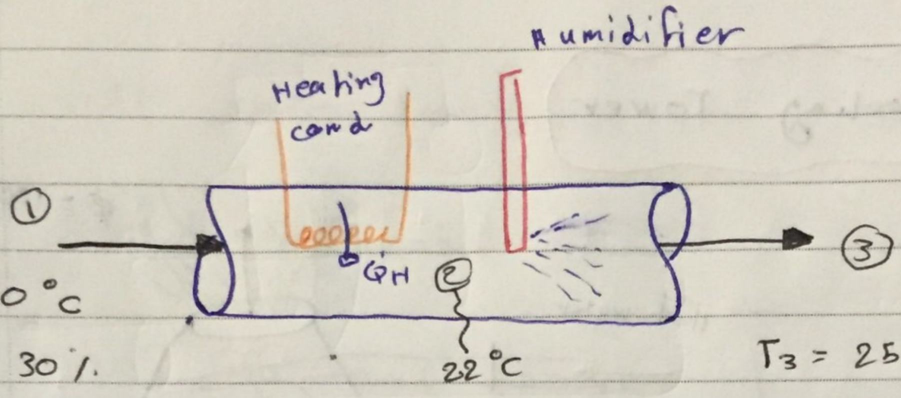
# Cooling Tower



$$\dot{m}_{makeup} = \dot{m}_a (w_2 - w_1)$$

$$\dot{m}_a = \frac{\dot{m}_3 (h_3 - h_4)}{(h_2 - h_1) - (w_2 - w_1) h_4}$$

EX: 14-5



$T_1 = 10\,°C$

$\phi = 30\,\%$

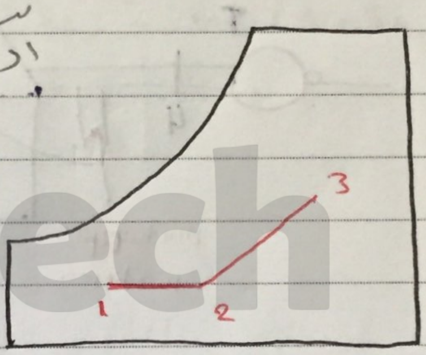
$V_1 = 45\ \frac{m^3}{min}$

$T_3 = 25°C$

$60\ \%\ \underbrace{RH}$
Relative Humedity

$\boxed{P = 100\ Kpa} \Rightarrow$ يعني بنقدر نستخدم ال chart

Find $\dot{Q}_H = ??$



$\boxed{sol:}$ $\dot{Q}_H = \dot{m}_a\,(h_2 - h_1) = ??$

$\dot{m}_f = \dot{m}_a\,(w_3 - w_2)$

$P_{g_1}$ = from tables = 3.233

$h_{g_1}$ = from table = 2519.2 $\frac{KJ}{Kg}$

$P_{v_1} = \phi_1\ P_{g_1} = 0.368$

$P_{a_1} = P - P_{v_1} = 99.632\ KPa.$

$w_1 = 0.622\ \frac{P_v}{P_a} = 0.023$

$h_1 = cp\ T_1\ 4\ w_1\ hg_1$

$= 1.005 * 10 + 0.0023 * 2519.2 = 15.8\ \frac{KJ}{Kg}$

Ex 14.6 "مهم جداً"

No.

$h_2 = c_p T_2 + \omega_2 h_{g_2}\Big|_{22°C}$

$= 1.005 (22) + 0.0023 (2541)$

$= 28$ KJ / Kg

$v_{1_{dry\ air}} = \frac{RT_1}{P_{a1}} = 0.815$

$\dot{m}_a v_1 = \dot{V}$

$\dot{m}_a = 55.2$ Kg/min.

$\dot{Q}_H = 673$ KJ /min

$\omega_3 = \frac{0.622 \ \phi \ P_{g3}}{P - \phi P_g}$

$P_{g3} = 3.1698$ , $\omega_3 = 0.001206$

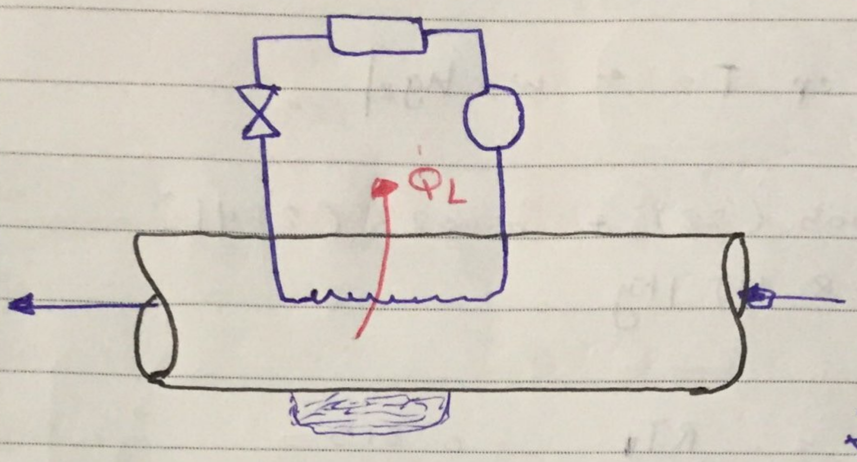
use chart

① 10°C, 30% } $h_1 = 16$, $\omega_1 = 0.0023$, $v_1 = 0.81$

③ 25°C, 60% } $\omega_3 = 12 \times 10^{-3}$

② 22°C, $\omega_1 = \omega_2$ } $h_2 = 28$

## Ex 14.6



14 °C
sat 2

1atm , 30°C
80% RH
$\dot{V} = 10 m^3/min$

**solution**

30°
$\phi$ 80%

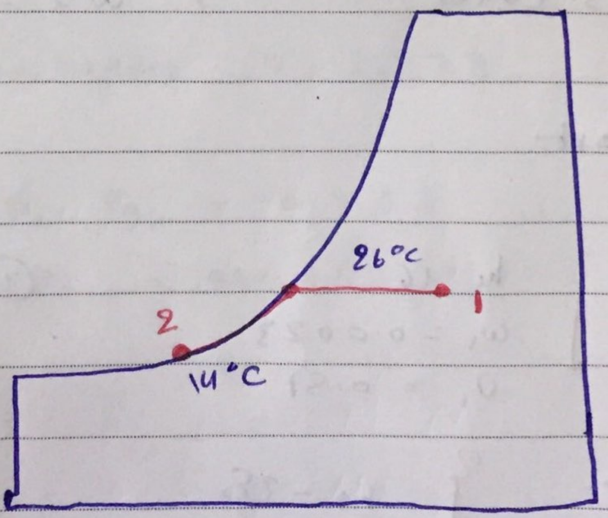
$T_{db} = 26°C$

في تكثف

14°C

$$\dot{Q}_L = \dot{m}_a(\underset{air}{h_1} - \underset{in}{h_2}) - \dot{m}_f h_f$$

$$\dot{m}_f = \dot{m}_a\left( w_1\big|_{26°C} - w_2\big|_{14°C} \right)$$



No.

chapter 15

# Chemical Thermodynamics.

$F + A \rightarrow P$ product

reactants

$C + O_2 \rightarrow CO_2$

→ ما بنستخدم ال moles في المعادلة

→ نستخدم ال mass او عدد الذرات. } في موازنة المعادلة

| | $C$ | $+ O_2$ | $= CO_2$ |
|---|---|---|---|
| moles | 1 | 1 | 1 |
| mass | 12 | 32 | 44 ~ 12+32 |
| عدد الذرات<br># atoms. | 1 | 2 | 3 |

$NM = m$

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Air $N_2$ 79% } by volume.
$O_2$ 21%

$0.21\ O_2 + 0.79\ N_2.$

$O_2 + 3.76\ N_2$

$\rightarrow CH_4 + 2(O_2 + 3.76\ N_2) \rightarrow CO_2 + 2H_2O + 7.52\ N_2$

No.

complete campustion ← المعادلة التي فيها ٢ شروط تسمى

① $C \rightarrow CO_2$

② $H_2 \rightarrow H_2O$ كل C تتحول لـ $CO_2$

③ $S \rightarrow SO_2$

نسبة كبريت

④ لا توجد اي ذرة أكسجين على اليمين غير مستخدمة "لوحدها"

→ stoichiometric theoretical 100 % th.

صيغة الوقود : $A\,C_x H_y O_z + B_{th} (O_2 + 3.76N_2)$

$\longrightarrow x_1\, CO_2 + x_2\, H_2O + x_3 N_2$

كمية الهواء اللازمة للإحتراق الكامل

البنزين المستخدم للسيارات { $C_8H_{18}$ $CH_3OH$

$C: \quad A * X * 12 = X_1 * 1 * 12$

$$\boxed{X_1 = AX}$$

$H: \quad A * Y * 1 = X_2 * 2 * 1$

$$\boxed{X_2 = \frac{AY}{2}}$$

$$O_2 : \quad A * Z * 16 + B_{th} * 2 * 16 = X_1 * 2 * 16 + X_2 * 1 * 16$$

$$B_{th} = A\left(x + \frac{y}{4} - \frac{z}{2}\right)$$

$$N : \quad B_{th} * 3.76 * \cancel{2}(\cancel{14}) = X_3 * \cancel{2} * \cancel{14}$$

$$X_3 = 3.76\, B_{th}.$$

$$A\, C_xH_yO_z + A\left(x + \frac{y}{4} - \frac{z}{2}\right)(O_2 + 3.76\, N_2)$$

$$\rightarrow A x\, CO_2 + \frac{Ay}{2} H_2O + 3.76\, B_{th}\, N_2$$

$$C_xH_yO_z + \left(x + \frac{y}{4} - \frac{z}{2}\right)(O_2 + 3.76\, N_2)$$

$$\rightarrow x\, CO_2 + \frac{y}{2} H_2O + 3.76 \frac{B_{th}}{A} N_2$$

$$C_8H_{18} + \left(8 + \frac{18}{4}\right)(O_2 + 3.76\, N_2) \rightarrow 8\, CO_2 + 9\, H_2O$$

$$12.5 + 3.76\, N_2$$

✓

نسبة
الهواء
الوقود

$$\left(\frac{A}{F}\right)_s = \frac{12.5\,(32 + 3.76 \times 28)}{114} = 15$$

$\phi$ = equivalence Ratio.

$$= \frac{A/F}{(A/F)_a} \begin{cases} <1 & \text{lean mixture} \to X_u O_2 \\ =1 & \\ >1 & \text{Rich mixture} \to X_u CO \end{cases}$$

$$Q_H = \sum N_P \left( \overline{h}_{T,P} - \overset{\text{reference point.}}{\overline{h}^\circ_{25^\circ C}} \right) - \overline{h}^\circ_f$$

$$- \sum N_R \left( \qquad \right) - \overline{h}^\circ_f$$